Geological Fieldwork 1984

A Summary of Field Activities
And Current Research

PAPER 1985 – 1

Province of
British Columbia

Ministry of
Energy, Mines and
Petroleum Resources

GEOLOGICAL BRANCH
MINERAL RESOURCES DIVISION

BC

85-3078/

Editor:
W. J. McMillan

Peer Review:
Ministry Geologists

Manuscript Input:
D. Bulinckx
N. Chan
D. Fehr

Draughting:
J. Armitage
P. Chicorelli
M. Taylor
M. Fournier
Authors

Pagination and Output:
R. Moir
D. Fehr
J. Patenaude

Geological Fieldwork
1984

---

a summary of field activities and
current research by the geological branch,
mineral resources division

Paper 1985-1

Province of British Columbia
Ministry of Energy, Mines and Petroleum Resources

British Columbia Cataloguing in Publication Data
Main entry under title:
Geological fieldwork. -- 1974-

(Paper, ISSN 0226-9430)
Annual.
Issuing body varies: 1974-1980, Geological Division; 1981-   , Geological Branch.
Subseries, 1979-   , of: Paper (British Columbia. Ministry of Energy, Mines and Petroleum Resources)
"A summary of field activities of the Geological Division, Mineral Resources Branch."
ISSN 0381-243X = Geological fieldwork

1. Geology - British Columbia - Periodicals. 2. Geology, Economic - British Columbia - Periodicals. 3. Mines and mineral resources - British Columbia - Periodicals. I. British Columbia. Geological Division. II. British Columbia. Geological Branch. III. British Columbia. Ministry of Energy, Mines and Petroleum Resources. IV. Series: Paper (British Columbia. Ministry of Energy, Mines and Petroleum Resources)

QE187.G46 1974   557.11'05

FOREWORD

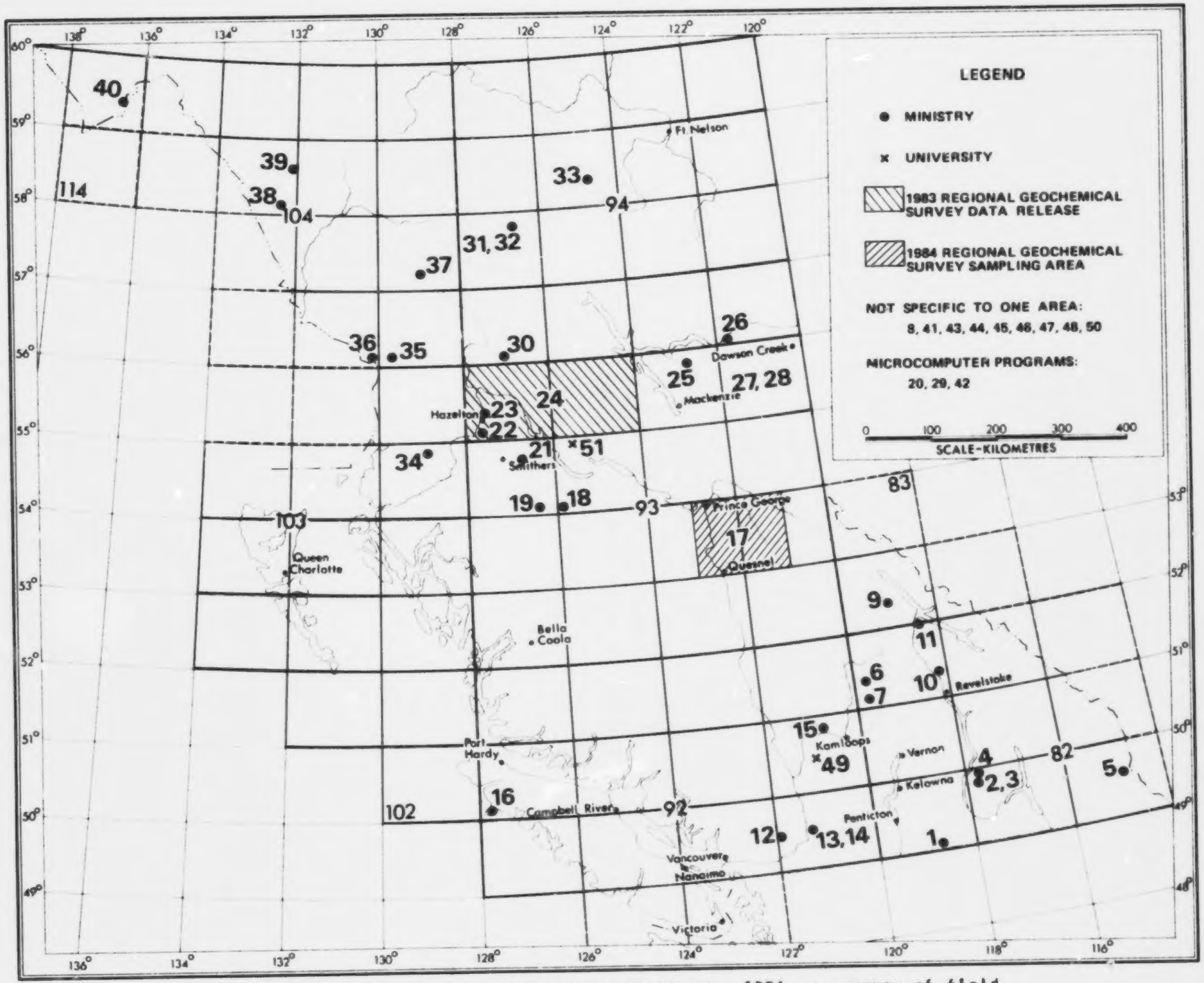
This is the eleventh year of publication of *Geological Fieldwork* and the first year it has been named *Geological Fieldwork, A Summary of Field Activities and Current Research*. The new name reflects expansion of the scope of this publication to include reports that cover the entire spectrum of work carried out by the Geological Branch. Reports on the two main inventory files of the Branch, MINFILE and COALFILE, are included for the first time. The main aim of the publication remains unchanged; to acquaint the interested public with preliminary results of fieldwork of geologists of the Geological Branch as soon as possible after the field season.

The 1984 field program, like 1983, was reduced in comparison to previous years as British Columbia entered the second year of fiscal restraint. Those geologists in the field had shortened field seasons and none had more than one field assistant. Others were confined to the office, completing long-term projects.

This edition has a three-section format; within each section, reports are sequenced according to NTS. The Project and Applied Geology section includes reports on field mapping and property examinations conducted by both Project and District Geologists. The Resource Data section consists of reports on MINFILE, COALFILE, land use issues, and assessment reports. The Other Investigations section consists of four papers submitted by researchers at the University of British Columbia; each represents a cooperative project.

The cover photograph shows Ministry geologist Andre Panteleyev examining a massive sulphide lens on the Cariboo Hudson property near Wells.

W. R. Smyth,
Chief Geologist,
Geological Branch,
Mineral Resources Division.


LEGEND
● MINISTRY
× UNIVERSITY
▨ 1983 REGIONAL GEOCHEMICAL SURVEY DATA RELEASE
▨ 1984 REGIONAL GEOCHEMICAL SURVEY SAMPLING AREA
NOT SPECIFIC TO ONE AREA:
8, 41, 43, 44, 45, 46, 47, 48, 50
MICROCOMPUTER PROGRAMS:
20, 29, 42
0 100 200 300 400
SCALE-KILOMETRES
Ft. Nelson
Dawson Creek
Mackenzie
Hazelton
Smithers
Prince George
Quesnel
Queen Charlotte
Bella Coola
Port Hardy
Campbell River
Vancouver
Nanaimo
Victoria
Kamloops
Vernon
Kelowna
Penticton
Revelstoke
40
39
38
33
31, 32
37
36
35
30
26
25
27, 28
23
22
24
21
×51
34
19
18
17
9
11
10
6
7
15
×49
4
2, 3
5
1
12
13, 14
16
114
104
94
103
93
83
92
82
102
60°
59°
58°
57°
56°
55°
54°
53°
52°
51°
50°
49°
48°
138°
136°
134°
132°
130°
128°
126°
124°
122°
120°
118°
116°

Distribution of programs: Geological Fieldwork, 1984, a summary of field activities and current research by the Geological Branch, Mineral Resources Division (Paper 1985-1).

TABLE OF CONTENTS

Page

GEOLOGICAL BRANCH - WHO TO CONTACT, WHERE, AND WHAT FOR 16

PROJECT AND APPLIED GEOLOGY

1 *Church, B. N.*: Geology of the Mount Attwood-Phoenix Area, Greenwood (82E/2) 17

2 *Kwong, Y.T.J.*: The Tillicum Mountain Gold Prospect - A Petrologic Update (82F/13) 23

3 *Ray, G. E., McClintock, J.*, and *Roberts, W.*: Tillicum Mountain Gold-silver Project (82F/13, 82K/4) 35

4 *Addie, G. G.*: Self-potential Tests at the Silver Queen Prospect near Tillicum Mountain and the Hailstorm Mountain Gold Prospect (82F) 49

5 *Grieve, D. A.* and *Kilby, W. E.*: Structural Modelling of Parts of the Northern Dominion Coal Block (Parcel 73), Southeastern British Columbia (82G/10) 53

6 *Goutier, F., Godwin, C. I.*, and *Höy, T.*: Mineral Deposits in the Birk Creek Area: An Introduction to a Metallogenic Study of the Adams Plateau-Clearwater Area (82M) ... 67

7 *White, G.P.E.*: Hilton Massive Sulphide Discovery (Rea Gold), Johnson Creek-Adams Lake Area (82M/4W) 77

8 *Pell, J.*: Carbonatites and Related Rocks in British Columbia (82L, 83D, 93I, 93N) 85

9 *White, G.P.E.*: Further Notes on Carbonatites in Central British Columbia (83D/6E, 7W) 95

10 *Höy, T.*: J & L, A Stratabound Gold-arsenic Deposit, Southeastern British Columbia (82M/8) 101

11 *Gibson, G.* and *Höy, T.*: Rift, A Zinc-lead Massive Sulphide Deposit in Southeastern British Columbia (82M/15) 105

12 *Ray, G. E.* and *Coombes, S.*: Harrison Lake Project (92H/5, 12; 92G/9, 16) 120

13 *Ray, G. E.* and *Niels, R.J.E.*: Surface and Underground Geological Structures at Carolin Gold Mine (92H/11) 133

14 *Ray, G. E.* and *Niels, R.J.E.*: Element Zoning Associated with Gold Mineralization at Carolin Mine (92H/11) 139

15 *Mihalynuk, M.* and *White, G.P.E.*: Tertiary/Triassic Lithogeochemical Study, North Kamloops Lake Area (92I/10, 15) 151

16 *Smyth, W. R.*: Geology of the Brooks Peninsula, Vancouver Island (92L/4) 161

17 *Schmitt, H. R.*: Regional Geochemical Survey 12: Prince George (East Half) and McBride (West Half) (93G/E, 93H/W, 93H/2) 171

TABLE OF CONTENTS *(CONTINUED)*

Page

PROJECT AND APPLIED GEOLOGY *(CONTINUED)*

18 *Schroeter, T. G.*: Eagle Creek Opal Occurrence (93K/4W) 173

19 *Church, B. N.*: Update on the Geology and Mineralization in the Buck Creek Area - the Equity Silver Mine Revisited (93L/1W) 175

20 *Church, B. N.*: A Computer Program for the Estimation of Oxide Composition from Modal Analyses of Plutonic Rocks from the Buck Creek Area (93L/1W) 189

21 *MacIntyre, D. G.*: Geology of the Dome Mountain Gold Camp (93L/10, 15) 193

22 *White, G. V.*: The Seeley Lake Coal Prospect (93M/4E) 215

23 *Schroeter, T. G.*: Pink Cadillac Silver Prospect (93M/5E) 219

24 *Schroeter, T. G.* and *White, G. V.*: British Columbia Regional Geochemical Survey (RGS) Data Release: Summary of Results (93M, N) 223

25 *Legun, A.*: Geology of the West Carbon Creek Area (93O/15) ... 227

26 *Kilby, W. E.* and *Oppelt, H. P.*: Numerical Depositional Modelling - Gething Formation along the Peace River (93O, 94A, 94B) 233

27 *Legun, A.*: Eastern Limit of Upper Coal Measures of the Gething Formation (Chamberlain Member), Peace River Coalfield (93P) 251

28 *Kilby, W. E.*: Tonstein and Bentonite Correlations in Northeast British Columbia (93O, P, I; 94A) 257

29 *Kilby, W. E.*: SECTION - A Micro-computer Program (93, 94) ... 279

30 *Schroeter, T. G.* and *White, G. V.*: The Sustut Coal Measures (94D) 285

31 *Schroeter, T. G.*: Toodoggone River Area (94E) 291

32 *Diakow, L. J.*: Potassium-argon Age Determinations from Biotite and Hornblende in Toodoggone Volcanic Rocks (94E) 299

33 *Legun, A.*: Stream Sediment Sampling of the Wokkpash Park Proposal Area (94K/7) 301

34 *Schroeter, T. G.*: Kalum Property (Treadwell) (103I/15W) 303

35 *Dupas, Jacques P.*: Geology of the Spider Claim Group on Long Lake (104A/4) 308

36 *Alldrick, D. J.*: Stratigraphy and Petrology of the Stewart Mining Camp (104B/1) 316

37 *Koo, J.*: Coal Geology of the Mount Klappan Area in Northwestern British Columbia (104H/2, 3, 6, 7) 343

TABLE OF CONTENTS *(CONTINUED)*

Page

PROJECT AND APPLIED GEOLOGY *(CONTINUED)*

38 *Schroeter, T. G.*: Muddy Lake Prospect (104K/1W) 353

39 *Schroeter, T. G.*: Heart Peaks Prospect (104K/9E) 359

40 *MacIntyre, D. G.* and *Schroeter, T. G.*: Mineral Occurrences in the Mount Henry Clay Area (114P/7, 8) 365

41 *Hora, Z. D.* and *Kwong, Y.T.J.*: Titanium in Tailings of Porphyry Deposits in British Columbia 381

42 *Addie, G. G.*: Slope Angle Correction Computer Program for a One-man Survey 389

RESOURCE DATA AND ANALYSIS

43 *Ratel, A.*: Mineral Resource Assessments - Activities of the Land Use Office 393

44 *Wilcox, A., Gardiner, M.,* and *Sturko, C.*: Assessment Reports . 397

45 *Kenyon, Candace E.*: COALFILE 399

46 *Thompson, B. J.* and *Matheson, A.*: Canada/British Columbia Coal Data Project 403

47 *Wilcox, A.* and *Ritchie, C.*: MINFILE - Past, Present, and Future 405

OTHER INVESTIGATIONS

48 *Goldsmith, L. B.* and *Sinclair, A. J.*: Multiple Regression, A Useful Quantitative Approach in Evaluating Production Data from Vein-type Mining Camps, Southern British Columbia ... 411

49 *Tombale, A. R., Sinclair, A. J.,* and *McMillan, W. J.*: Variation of K/Rb Ratio in the Major Units of the Guichon Creek Batholith (92I) 419

50 *Spence, Andrée*: Shoshonites and Associated Rocks of Central British Columbia 426

51 *Godwin, C. I.* and *Cann, R.*: The Mac Porphyry Molybdenite Property, Central British Columbia (93K/13E) 443

FIGURES

Page

Distribution of programs 4

1 Detailed geology of the Greenwood mining camp 18

2 General geology and location of identified gold zones in the Tillicum Mountain gold property as of 1983 (geology after Hyndman, 1968; gold data courtesy of Esperanza-La Teko) 22

3 Generalized geology of the area studied in detail 25

4 ACF plot for selected samples from the Tillicum gold property showing prograde and retrograde assemblages 28

5 Simplified geology of the Tillicum-Grey Wolf Mountains area 36

6 Geology of the Heino-Money zone 44

7 Esperanza-Silver Queen self-potential test survey 48

8 Self-potential road traverse of Caribou Nos. 3 and 4 claims . 50

9 The Crowsnest Coalfield area, showing the locations of Parcels 73 and 82 of the Dominion Coal Block 53

10 Generalized geology of the southwest portion of Parcel 73 (modified after Ollerenshaw, *et al.*, 1977) 54

11 Measured stratigraphic section of Mist Mountain Formation on Hosmer Ridge (*see* Fig. 10 for location) 56

12 Isometric diagram of the surface topography of the study area with coal seams displayed; each net square is 100 metres on a side; and the view is that seen by looking down on the deposit in a southeasterly direction 58

13 Isometric net diagrmas related to the upper Lookout seam:
  (a) Display of the seams structure contour grid; the vertical drop-off marks the outcrop edge of the seam 60
  (b) View of the amount of material above the seam 60

14 Map displays showing the distribution of the waste to coal ratio values cumulated to the base of four coal seams 62

15 Regional geology of Adams Plateau-Clearwater area (after Schiarizza, *et al.*, 1984) showing sample locations and showings (Table 1); lithologic units are described in Table 2; and Birk Creek area (Figs. 16 and 18) is centred around showing No. 5 66

16 Birk Creek area showing lcoation of sections A-A', B-B', C-C', and D-D'... 68

17 Detailed sections A-A', B-B' from the north side of Birk Creek (sections about 350 metres apart, *see* Fig. 16) 72

18 Sketch of section D-D', looking south, showing location of major lithologic units, sulphides, and adits 74

19 Geology of the Hilton-Rea-Falconbridge area 78

20 Diagrammatic vertical southeast-northwest section, Hilton-Rea-Falconbridge area 80

FIGURES *(CONTINUED)*

		Page
21	Distribution of carbonatites and related rocks in British Columbia	84
22	Geological map of Bearpaw Ridge (northern end)	86
23	Geological map of the Howard Creek carbonatite occurrence ...	88
24	(a) Geology of the area south of Paradise Lake	90
	(b) Cross-section A-A', area south of Paradise Lake	91
25	Blue River area. Map showing carbonatite localities	96
26	Preliminary geological plan, Howard Creek carbonatite	98
27	J & L section, 10+350E crosscut	102
28	Map of the Revelstoke-Mica Creek area showing major tectonic elements and base metal occurrences	106
29	Map of the Bigmouth Creek-Nicholls creek area showing geological setting of the Rift zinc-lead(-copper) occurrence	108
30	Structural cross-section, for location and legend *see* Figure 29; the box indicates the approximate stratigraphic interval exposed in Rift Creek and diagrammed onto the section	109
31	Stratigraphy of the Nicholls Creek area and Rift Creek showing lithologic setting of Rift zinc-lead(-copper) occurrence	112
32	Detailed section through Rift massive sulphide lenses showing sample locations (Table 1) and Pb/Pb + Zn ratios	114
33	Equal area projection of structural elements in the vicinity of the Rift showing	116
34	Geology of the Doctors Point area, Harrison Lake	121
35	Model depicting development of cone sheet fracturing and associated veins to explain Doctors Point mineralization (adapted after Anderson and Jeffreys, 1936)	123
36	Geology between Fire Lake and Fire Mountain	125
37	Southwest-northeast geological section through Fire Mountain (for symbols *see* Fig. 36)	126
38	Regional setting of the Harrison Lake fault system	128
39	Geology of the Carolin mine vicinity, Hope, British Columbia	132
40	Geological sections across the Carolin mine area	134
41	D2 similar-type folds in Ladner Group bedded siltstones	136
42	Ladner Group - Carolin mine (surface)	137
43	Longitudinal cross-section through the Idaho zone - 837 North - showing location of drill holes IU-49 and IU-53	140

FIGURES *(CONTINUED)*

Page

44 Geology and trace element geochemistry of hole IU-49, Carolin mine 142

45 Geology and major element geochemistry of hole IU-49, Carolin mine 144

46 Geology and trace element geochemistry of hole IU-53, Carolin mine 146

47 Geology and major element geochemistry of hole IU-53, Carolin mine 148

48 Plan map showing sample locations, North Kamloops Lake study area 150

49 Histogram of copper in 68 Triassic Nicola/Iron Mask samples . 158

50 Histogram of copper in 67 Tertiary Tranquille Formation samples 158

51 Histogram of gold in Triassic Nicola/Iron Mask samples 159

52 Histogram of gold in Tertiary Tranquille Formation samples .. 159

53 Histogram of mercury in Triassic Nicola/Iron Mask samples ... 160

54 Histogram of mercury in Tertiary Tranquille Formation samples 160

55 Geological map, Brooks Peninsula, Vancouver Island 162

56 Location map for Regional Geochemical surveys carried out in British Columbia 170

57 Location and access map of Eagle Creek Opal occurrence 172

58 Geology of the Equity minesite 174

59a Volcanogenesis of the Buck Creek basin, Upper Cretaceous events 176

59b Volcanogenesis of the Buck Creek basin, Tertiary events 177

60 Elements of the Buck Creek caldera showing volcanic centres and anomalous arsenic localities 178

61 Composite lithogeochemistry for pathfinder and ore elements, Equity mine 180

62 Mixing diagram showing chemical and mineralogical consanguinity of Goosly intrusions in the Buck Creek area 183

63 Metallogenic model showing the stages of igneous intrusion leading to mineralization at the Equity Silver mine 186

64 Location of Dome Mountain gold camp and general geology of the Smithers map-area 192

65 Preliminary geology of the Dome Mountain gold camp 194

66 Preliminary stratigraphic column, Dome Mountain gold camp ... 196

67 Bedding, foliation, quartz vein, and fold axis trends, Dome Mountain gold camp 200

FIGURES *(CONTINUED)*

Page

68 Stereonet plots for bedding, foliation, quartz veins, and fold axes 204

69 Detailed geology of the Forks vein 205

70 Detailed geology of the Free Gold vein 206

71 Structural model, Dome Mountain gold camp 212

72 Geological setting of the Seeley Lake area in the Bowser Basin 214

73 Geology of the Seeley Lake coal licence area 216

74 Geological sketch map of the Pink Cadillac prospect 220

75 New staking (June 24 to July 1) and active claim status (April 1, 1984), Hazelton area, 93M 222

76 New staking (June 24 to July 1) and active claim status (April 1, 1984), Manson River area, 93N 224

77 Location of the West Carbon Creek map-area 227

78 West Carbon Creek map-area (930/15); geology of a major coal-bearing syncline is shown 228

79 Location map of diamond-drill holes examined along the Peace River 234

80 Schematic diagram of lithologies measured from the lower Moosebar and upper Gething Formations along the Peace River . 236

81 Legend of lithologies 237

82 Count, expected, and difference matrices for Gething Formation sediments; table summarizes abundance and average thickness of lithological units 240

83 Transition flow diagram illustrating significant transitions on the basis of strongly positive values in the difference matrix 241

84 Upward and downward transition probability matrices 242

85 Upward, downward, and mutual substitutability matrices for Gething sediments measured 244

86 Derived standard sedimentary sequence for the upper Gething Formation based on a Monte Carlo simulation of the upward transition probability matrix 246

87 Eastern limit of upper coal measures of Gething Formation (Chamberlain member) 250

88 Northwest-southeast line of section showing relationship of marine tongue to Gething Formation coal measures in the Peace River coalfield 252

89 Correlation of marine tongue, upper and lower member of the Gething Formation 254

FIGURES *(CONTINUED)*

Page

90 Location map of borehole sites used in the tonstein and bentonite correlation examples; section lines indicate the order in which the holes appear on the various sections 256

91 Schematic regional stratigraphic section illustrating the position and extent of major ash horizons examined in this study 258

92 Bentonites in the lower Hulcross Formation; bentonites appear as strong gamma responses 260

93 Twin bentonite horizons and the Gething-Moosebar formational contact 262

94 Borehole geophysical traces of the lower Moosebar to Bluesky interval north of the Sukunka River area; column 4 is exaggerated due to bedding to core angles of 50 degrees 263

95 Detailed sections of the Fisher Creek tonstein zone from widely spaced borehole and outcrop locations 266

96 (a) Correlation coefficient matrix of 13 elements from 58 samples of Moosebar and Gething Formations altered ash bands; significant positive and negative values are highlighted 268

(b) Dendogram constructed from the correlation coefficient matrix by the weighted pair-group clustering method 269

97 Ternary plot of $SiO_2/Al_2O_3/CaO$ for all 58 samples; note the consistent SiO_2/Al_2O_3 ratio of about 1.66:1 which does not vary as the percentage of CaO changes 270

98 TiO_2 versus Zr plot 270

99 Similarity coefficient dendogram of 60 samples calculated by the weighted pair-group clustering technique 272

100 Geophysical logs from two borehole sections of the lower Moosebar and Bluesky sequences 273

101 Correlation example from Gething Formation coal zone: a trench and borehole section are correlated on the basis of similarity coefficients; the fault locations and seam duplications were determined by examination of the geophysical log trace and similarity coefficients; dashed correlation lines indicate correlations with high similarity coefficients but not the mutually highest coefficients between the two samples 274

102 Example of X-ray diffractograms of four tonsteins illustrated on Figure 101: the chemical similarity coefficients are given in matrix form to provide a comparison between mineralogical and chemical similarities; the XRD measurement rate was °2 θ/min and samples were bombarded with FeKα radation 276

FIGURES *(CONTINUED)*

Page

103 Hypothetical geologic map data; the figure consists of a map view showing a syncline plunging to the southeast and a table with numerical equivalents of the data displayed on the map 278

104 Cross-section plots of data projected onto two different planes of section: (a) profile A-A', constructed normal to the projection direction (fold-axis), (b) vertical east-west section A-B' 280

105 Example of screen display during program execution; user input is underlined 282

106 Sustut coal licences, property location map 284

107 Regional geology of the area northeast of Bear Lake 286

108 Stratigraphic section of sedimentary rocks of the Upper Bowser Lake Formation 288

109 Mineral properties, Toodoggone River area 292

110 Schematic composite stratigraphic section illustrating the relative position of major Toodoggone lithologic units from which K/Ar radiometric dates have been obtained 298

111 Location map and stream sediment sampling sites, Wokkpash Park Proposal area 302

112 Plan of part of Kalum property 304

113 Geology of the Spider claim group on Long Lake, Stewart, British Columbia 310

114 Geological cross-section A-A', Spider claim group 311

115 Geology and major mineral deposits, Salmon River area 318

116 Schematic cross-section showing stratigraphic position of mineral deposits, Salmon River area 322

117 Metallogeny, evolution, and paleotopography of andesitic stratovolcano 324

118 Compositions of 16 volcanic and volcaniclastic rocks analysed from Salmon River area 330

119 Geology of the Mount Klappan area 342

120 Geological cross-sections of the Mount Klappan area 344

121 Geological plan of the Muddy Lake prospect 352

122 Schematic sections showing relationships of alteration and mineralization, Muddy Lake prospect 354

123 Geological plan of the Heart Peaks prospect 358

124 Location of the Mount Henry Clay area relative to major tectonic elements as defined by Campbell and Dodds (1983) 365

FIGURES *(CONTINUED)*

Page

125 General geology and location of mineral occurrences, Mount Henry Clay area [British Columbia geology after Campbell and Dodds, 1983; Alaska geology after Redman (Still, 1984)] 366

126 Generalized stratigraphic columns for the Windy-Craggy and Mount Henry Clay areas showing approximate position of mineral occurrences 368

127 Stability fields of phases common in submarine exhalative deposits when formed from a solution with total Cl^- = 1M; pO_2= 10 atm; pH = 4 378

128 Diagram outlining the survey method 389

129 Mineral potential of Chilko Lake 394

130 Geological Branch computing network 400

131 Typical MINFILE printout 406

132 Observed versus calculated tonnages using a multiple regression equation, Slocan camp 413

133 A plot of average K/Rb ratios of major units of the Guichon Creek batholith versus K (weight per cent) 420

134 Rb versus SiO_2, Guichon Creek batholith 421

135 Upper Triassic shoshonites--MgO:CaO plot designed to screen 'unaltered' (filled circles), 'altered' (open circles) samples, and samples with 'added Ca' or plagioclase cumulates (squares) 438

136 Upper Triassic shoshonites--MgO:SiO_2 plot, notice absence of data points above the 'subalkaline' domain 438

137 Upper Triassic shoshonites--CaO:SiO_2 plot shows majority of 'unaltered' data points in 'subalkaline' domain 439

138 Upper Triassic shoshonites--Na_2O:SiO_2 plot shows most data points in 'subalkaline' domain; those above it have lower K_2O contents 439

139 Upper Triassic shoshonites--K_2O:SiO_2 plot illustrates the highly potassic nature of the shoshonites 440

140 Upper Triassic shoshoites--Alk:SiO_2 plot illustrates the alkaline nature of the shoshonites; the extremely alkaline samples are leucite phonolites 440

141 Upper Triassic shoshonites--FeO_T:SiO_2 plot; 'Fe-rich' (tholeiitic) and 'Fe-poor" (calc-alkaline) domains defined from plot of pigeonitic and hypersthenic suites of Japan 441

142 Upper Triassic shoshonites--Al_2O_3:SiO_2 plot shows the increase in Al_2O_3 with differentiation 441

FIGURES *(CONTINUED)*

Page

143 Upper Triassic shoshonites--TiO_2:FeO_T designed initially for subalkaline basalts with 48 per cent $\leqslant$ SiO_2 $\leqslant$ 50.5 per cent 442

144 Generalized geology of the Mac porphyry molybdenum prospect.. 444

PLATES

I Native gold (Au), pyrrhotite (Po), and sphalerite (Sp), with or without tetrahedrite, fill the interstitial spaces between tremolite crystals and partially resorbed, rounded grains of diopside 30

II Native gold (Au) is associated with marcasite (ma) and locally pyrite (py) that have almost completely replaced pyrrhotite (Po) 30

III Late-stage native gold (au) forms a discontinuous train of blebs along a fracture that cuts pyrrhotite (Po) and pyrite (py) 31

IV Panoramic view of Equity Silver mine 175

V Pulaskite dyke with sulphide ponded (?) at the footwall contact, veinlets of ore sulphides occur within the dyke ... 184

VI Photomicrograph of a sulphide veinlet within the Tertiary pulaskite dyke 184

VII Foliated and folded quartz veins in the wallrock of the Cabin vein 202

VIII Folded and brecciated quartz, Raven vein 202

IX Dark clasts in pervasively altered and foliated tuff, Low Herbert showing 373

X View of the Glacier Creek Main (Haines Barite) deposit 375

XI View of Mount Henry Clay looking south 377

GEOLOGICAL BRANCH

WHO TO CONTACT, WHERE, AND WHAT FOR

RON SMYTH – 387-5975
Chief Geologist
Room 418, Douglas Building
617 Government Street
Victoria V8V 1X4

NORMA CHAN – 387-5975
Secretary
Room 418, Douglas Building

RESOURCE DATA AND ANALYSIS
Room 418, Douglas Building
387-5975

GIB McARTHUR
Manager

RECEPTIONIST (postion vacant)

GEOLOGIST (position vacant)
Regional Mineral Resource Assessments

ANN RATEL
Land Use Coordination

TALIS KALNINS
Assessment Report Approval

ALLAN WILCOX
Mineral Inventory

CINDY RITCHIE
MINFILE

MARLENE GARDINER
Assessment Reports, Index, and Maps

Room 200, 756 Fort Street
Victoria V8W 3A3
387-1301

DANNY HORA
Industrial Minerals and Aggregates

ALEX MATHESON
CLAUDIA STURKO
Coal Assessment Report Approval and Coal Resources Information

CANDACE KENYON
COALFILE and Computer Applications

BEV GORDON
Receptionist

GEOSCIENCE PROJECTS
Room 300, 756 Fort Street
Victoria V8W 3A3
387-5068

BILL McMILLAN
Manager/Porphyry Deposits/Geochemical Surveys/Mineral Deposits in Triassic Rocks

DEBBIE BULINCKX
Receptionist/Manuscript Preparation

PROJECT GEOLOGISTS

NEIL CHURCH
South Central and Central British Columbia Volcanic Terrains, Tertiary Basins, Precious Metals and Coal

TRYGVE HØY
Southeastern British Columbia/Lead-Zinc Deposits/Sedimentary and Metamorphic Terrains/Metallogeny

ANDRE PANTELEYEV
Northern and Central British Columbia/Gold, Porphyry, and Massive Sulphide Deposits

DON MacINTYRE
Northern and Central British Columbia/Volcanic and Sedimentary Hosted Massive Sulphide Deposits

GERRY RAY
South Central and Southwestern British Columbia/Gold Deposits in Ultramafic and Metamorphic Terrains

DANI ALLDRICK
Stewart and Cariboo Areas/Gold and Lead-Zinc Deposits/Volcanic and Sedimentary Terrains

WARD KILBY
Peace River Coalfield/Correlation Computer Applications, Coal Quality

JAHAK KOO
Northwestern Coalfield/Sedimentology, Structure, Correlation, Coal Quality

ANALYTICAL LABORATORY
541 Superior Street
Victoria V8V 4S2
387-6249

WES JOHNSON
Chief Analyst/Geochemistry/Coal Liquids

LYNN BYRNELL
Secretary

PAUL RALPH
Deputy Chief/Supervising Analyst/Computer Applications

JOHN KWONG
X-Ray Diffraction/Mineralogy

VERNA VILKOS
X-Ray Fluorescence

MAC CHAUDHRY
Emission Spectrography

BISH BHAGWANANI
Atomic Absorption Flame Spectrophotometry of Base Metals

FRANK KARPICK
Fire Assay for Precious Metals

APPLIED GEOLOGY
Room 200, 756 Fort Street
Victoria V8W 2A3
387-5538

VIC PRETO
Manager/Director of Prospectors Assistance/Mineral Deposits of South Central British Columbia

GERI DICKSON
Secretary/Prospectors Assistance

DISTRICT GEOLOGISTS

PAUL WILTON
Victoria District/Assistant Manager/Prospectors Assistance and Training Vancouver Island, Lower Mainland

TOM SCHROETER – 847-7391
GARY WHITE – 847-7386
Smithers District/Northwest British Columbia/Northwest Coalfield
Bag 5000, 3793 Alfred Avenue
Smithers V0J 2N0

ANDREW LEGUN – 785-6906
KEN CLARKE
Fort St. John District/Northeast Coalfield/Coal Core Library
Box 7438, Fort St. John V1J 4M9

TED FAULKNER – 565-6125
Prince George District/
Central British Columbia
1652 Quinn Street
Prince George V2N 1X3

GORDON WHITE – 828-4566
Kamloops District/
South Central British Columbia
101, 2985 Airport Drive
Kamloops V2B 7W8

GEORGE ADDIE – 352-2211 (Ext. 303)
Nelson District/
South Central British Columbia
403 Vernon Street, Nelson V1L 4E6

DAVE GRIEVE – 423-6884
Fernie District/Southeast Coalfield
Mine Rescue Station, Cranbrook Road
Box 1290, Fernie V0B 1M0

PROJECT AND APPLIED GEOLOGY

GEOLOGY OF THE MOUNT ATTWOOD-PHOENIX AREA, GREENWOOD
(82E/2)

By B. N. Church

INTRODUCTION

Regional mapping of 250 square kilometres in the Mount Attwood-Phoenix area near Greenwood has been prompted by continuing mineral exploration mainly by Noranda Mines, Ltd. and Kettle River Resources Ltd. This mapping utilizes the Granby Mining Company Ltd.'s 1:12 000-scale topographic base map and information from previous detailed studies of the Lexington mine (Church, 1970), Oro Denoro mine (Church, 1983), Skomac mine (Church, 1977), Sappho (Church and Robertson, 1983), and Sylvester K (Church, 1984) prospects.

The Mount Attwood-Phoenix area is underlain by 22 mappable units comprising a variety of sedimentary, volcanic, metamorphic, and intrusive rocks that range from Paleozoic to Tertiary in age (Fig. 1).

BEDDED ROCKS

The Paleozoic (?) age Knob Hill Group is the oldest of four major mutually unconformable assemblages. These rocks consist of massive and banded metacherts and lesser amounts of quartz-chlorite schist, some amphibolitic schists and gneisses, and a few marble bands. The rocks have been affected by deformation and metamorphism causing recrystallization and the development of foliation, quartz sweats parallel to foliation and much deformation of individual beds.

The Attwood Group is Permo-Carboniferous, according to much fossil evidence. The rocks consist mainly of black argillite, some sharpstone conglomerate beds, greywacke, limestone lenses, and metavolcanic units.

The Brooklyn Group is Triassic and commonly overlies Knob Hill rocks in 'valleys' eroded through the Attwood sequence. It is characterized by

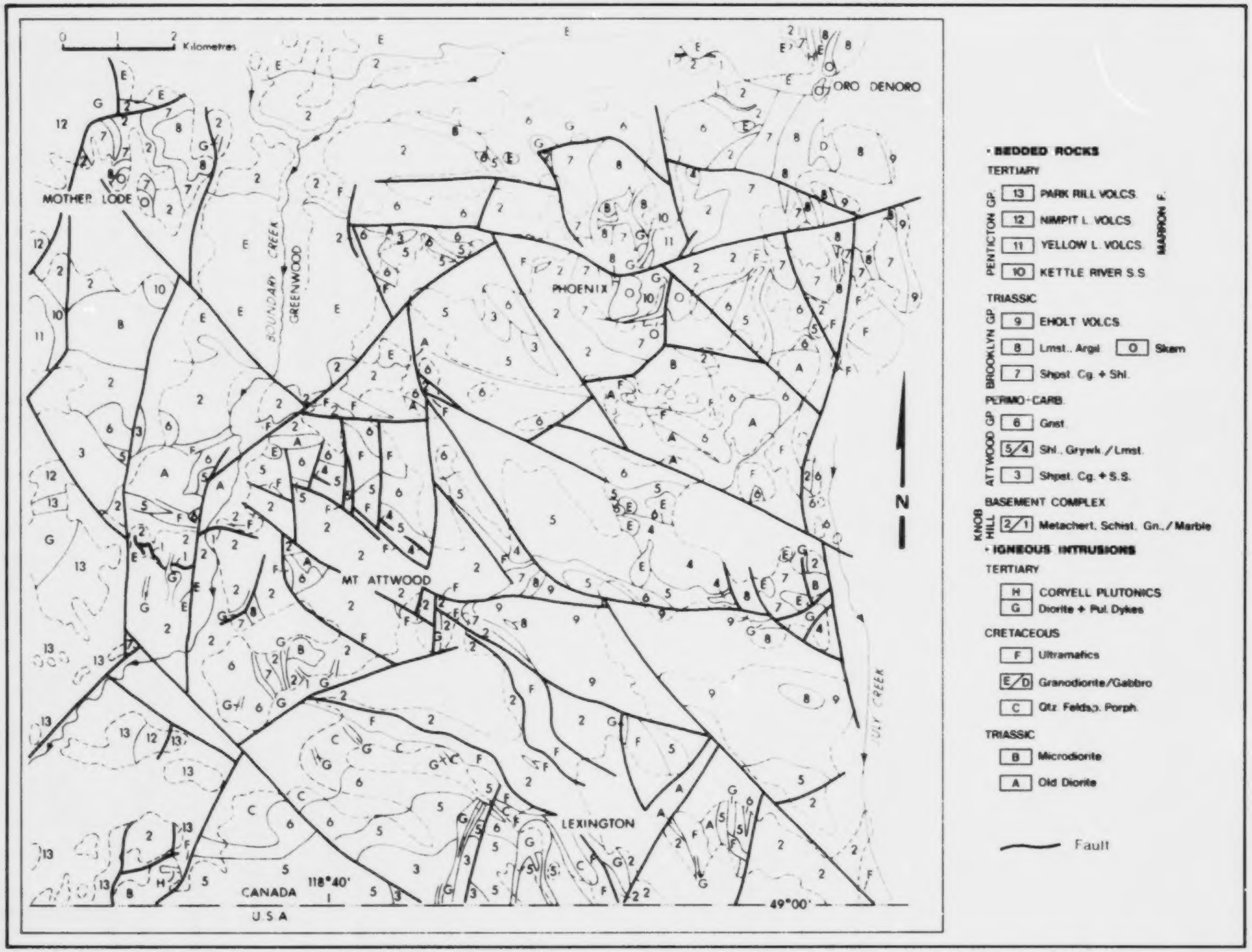

0 1 2 Kilometres
MOTHER LODE
ORO DENORO
PHOENIX
MT ATTWOOD
LEXINGTON
BOUNDARY CREEK
GREENWOOD
JULY CREEK
CANADA
U.S.A.
118°40'
49°00'
N
• BEDDED ROCKS
TERTIARY
PENTICTON GP.
MARRON F.
13 PARK RILL VOLCS.
12 NIMPIT L. VOLCS.
11 YELLOW L. VOLCS.
10 KETTLE RIVER S.S.
TRIASSIC
BROOKLYN GP.
9 EHOLT VOLCS.
8 Lmst., Argil.
O Skarn
7 Shpst. Cg. + Shl.
PERMO-CARB.
ATTWOOD GP.
6 Gnst.
5/4 Shl., Grywk./Lmst.
3 Shpst. Cg. + S.S.
BASEMENT COMPLEX
KNOB HILL
2/1 Metachert, Schist, Gn./Marble
• IGNEOUS INTRUSIONS
TERTIARY
H CORYELL PLUTONICS
G Diorite + Pul. Dykes
CRETACEOUS
F Ultramafics
E/D Granodiorite/Gabbro
C Qtz. Feldsp. Porph.
TRIASSIC
B Microdiorite
A Old Diorite
Fault

Figure 1. Detailed geology of the Greenwood mining camp.

thick basal conglomerates, interfingering shales and limestones, and an upper sequence of volcanic breccias. Abundant chert clasts derived from the underlying Knob Hill formations characterize both the Attwood and Brooklyn sharpstone conglomerates.

Both Attwood and Brooklyn rocks were affected by chlorite to amphibole grade regional metamorphism and important tectonic movements. Locally this deformation resulted in development of tight recumbent and overturned folds.

The Eocene Penticton Group is the youngest assemblage in the area. This group comprises the Kettle River Formation consisting mostly of arkosic sandstones, and the Marron Formation consisting of three volcanic members - the Yellow Lake mafic phonolites, the Nimpit Lake tan trachytes, and the Park Rill andesites. These rocks have been tilted by block faulting related to graben development.

IGNEOUS INTRUSIONS

The igneous intrusions range from ultramafic rocks and a small gabbro stock to an assortment of granite to syenite and diorite plutonic rocks and related hypabyssal bodies. Ages range from Triassic to Tertiary.

The oldest intrusions are heterogeneous hornblende diorites. These occur as numerous small, stock-like bodies that are associated with major faults scattered across the central part of the map-area. Partly digested xenoliths of Attwood sedimentary and volcanic rocks are common in the diorite, suggesting a post-Permian age. Clasts of this diorite are found in the Brooklyn sharpstone conglomerate, indicating a probable Lower or Middle Triassic age for this intrusive rock.

The largest intrusions are the Greenwood and Wallace Creek batholiths. These biotite-hornblende granodiorite bodies are associated with many of the skarns and quartz veins in the area. Potassium/argon analyses of these rocks yield Upper Jurassic/Lower Cretaceous dates of 143±5 Ma and 125±5 Ma from Oro Denoro mine and the Dentonia mine at Jewel Lake, respectively.

Microdiorite intrusions are scattered widely across the map-area occurring as small stocks and feeder dykes to the Park Rill andesites and older andesitic volcanic rocks. The older microdiorite bodies, such as the 206±8 Ma Providence Lake stock, and the Hartford Junction and Buckhorn intrusions, are of special note because of the contained disseminated sulphides and their proximity to orebodies in host rocks.

Serpentinized ultramafic rocks are also widely distributed throughout the map-area. These rocks are assigned a Cretaceous age because of cutting relationships. The serpentine was intruded as sills and dyke-like bodies, probably in semi-solid state, along unconformity surfaces and in major fault zones. The serpentine is hosted by a variety of rocks types, including Knob Hill, Attwood and Brooklyn Formations, and phases of both the Greenwood batholith and the older diorites.

MINERALIZATION

Most mineral production in the Greenwood mining camp has been from copper skarn deposits. To a lesser extent, production has come from gold and silver-bearing quartz veins with ancillary lead and zinc values.

Recent exploration has focused on stratabound volcanogenic (?) gold-sulphide mineralization in Triassic beds (Sylvester K prospect) and precious metal veins peripheral to the Wallace Creek batholith (Dentonia mine at Jewel Lake). Other mineral occurrences of note, that have received current and past attention, are the Phoenix and Oro Denoro copper sulphide-magnetite-bearing skarn deposit, and the Lexington and Buckhorn porphyry copper prospects. The Tam O'Shanter prospect is a good example of epithermal vein mineralization associated with Tertiary faulting peripheral to the Toroda Creek graben. Sappho is a similarly situated gold-silver-platinum copper prospect hosted in a small Tertiary Coryell syenite-shonkinite intrusion. Older (Cretaceous) breaks containing dyke-like ultramafic intrusions have related gold-silver quartz vein systems, such as the Number 7 and the Skomac mines.

In the Greenwood area, the combination of a long history of mineralization and a wide range in types of deposits insures good potential for new discoveries.

REFERENCES

Church, B. N. (1970): Lexington, *B.C. Ministry of Energy, Mines & Pet. Res.*, GEM, 1970, pp. 413-425.

.... (1977): Geological Investigations in the Greenwood Area, *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1976, pp. 7-10.

.... (1983): Geology in Vicinity of the Oro Denoro Mine, *B.C. Ministry of Energy, Mines & Pet. Res.*, Geology in B.C., 1976, pp. G1-G13.

.... (1984): Geology and Self-potential Survey of the Sylvester K Gold-sulphide Prospect, *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1983, Paper 1984-1, pp. 7-14.

Church, B. N. and Robertson, S. (1983): Geology and Magnetometer Survey of the Sappho Gold-silver-platinum-copper prospect, *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1982, Paper 1983-1, pp. 27-31.

Little, H. W. (1983): Geology of the Greenwood Map-area, British Columbia, *Geol. Surv., Canada*, Paper 79-29, 37 pp.

McNaughton, D. A. (1945): Greenwood-Phoneix Area, British Columbia, *Geol. Surv., Canada,* Paper 45-20.

Seraphim, R. H. (1956): Geology and Copper Deposits of Boundary District, British Columbia, *C.I.M.*, Trans., Vol. LIX, pp. 384-394.

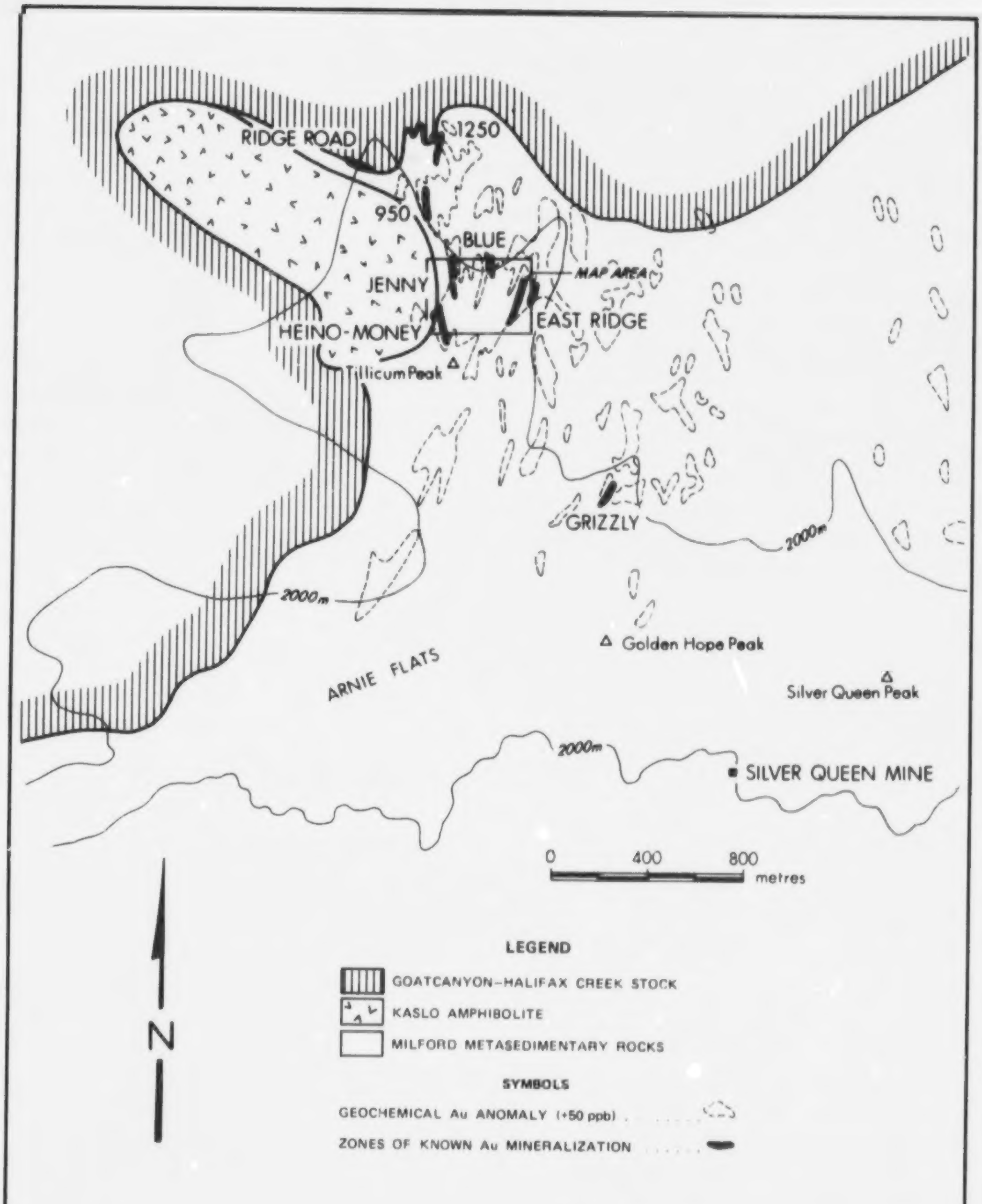

RIDGE ROAD
1250
950
BLUE
JENNY
MAP AREA
EAST RIDGE
HEINO-MONEY
Tillicum Peak
GRIZZLY
2000m
2000m
Golden Hope Peak
ARNIE FLATS
Silver Queen Peak
2000m
SILVER QUEEN MINE
0
400
800
metres
N
LEGEND
GOATCANYON-HALIFAX CREEK STOCK
KASLO AMPHIBOLITE
MILFORD METASEDIMENTARY ROCKS
SYMBOLS
GEOCHEMICAL Au ANOMALY (+50 ppb)
ZONES OF KNOWN Au MINERALIZATION

Figure 2. General geology and location of identified gold zones in the Tillicum Mountain gold property as of 1983 (geology after Hyndman, 1968; gold data courtesy of Esperanza-La Teko).

THE TILLICUM MOUNTAIN GOLD PROPERTY
A PETROLOGIC UPDATE
(82F/13)

By Y.T.J. Kwong

INTRODUCTION

The Tillicum Mountain gold property (latitude 49 degrees 59 minutes north, longitude 117 degrees 43 minutes west) is located approximately 13 kilometres east of Burton in the Arrow Lakes region of southeastern British Columbia. Shortly after the initial discovery of high-grade surface gold in 1980 by local prospectors, Arnold and Elaine Gustafson, the property was optioned to the Welcome North-Esperanza Joint Venture. In 1982, Esperanza Explorations Ltd. acquired the 50-per-cent interest of Welcome North Mines Ltd. and concluded a financial agreement with La Teko Resources Ltd. for further exploration. An intensive diamond drilling, prospecting, trenching, and sampling program has been carried out in subsequent field seasons.

The Tillicum Mountain gold prospect is a significant, relatively new find in the Province. Localized high-grade zones occur; the Money Pit, the original discovery, has already yielded a 64-ton bulk sample with 2.3 ounces gold per ton. In addition, several low-grade but large tonnage, roughly northerly trending zones of gold mineralization have been delineated. Moreover, recent exploration is also assessing two silver-dominated zones toward the southern boundary of the property.

The overlapping record of successive geological events, together with the fine grain size of many host rocks, have led to contrasting models of mineralization. Ideas put forward to explain the gold prospect range from skarn (Godwin, personal communication, 1983), to volcanogenic (Smith, 1983), to epigenetic and mesothermal (Kwong and Addie, 1982). To attempt to determine the genesis, a well-explored portion of the property was studied in detail. This communication presents findings on the petrology of the property and discusses their implications toward further exploration in the area. A model for the gold mineralization compatible with the new data is also proposed.

GEOLOGICAL SETTING

Tillicum Mountain lies in the southern extremity of the Nakusp area which was studied and mapped by Hyndman (1968). An extensive strip of rocks of the Milford (?) Group (Pennsylvanian (?) to Triassic) is intruded to the northwest by Cretaceous and/or Jurassic plutonic rocks of the Goatcanyon-Halifax Creeks stock (Fig. 2). The Milford Group consists of fine-grained pelitic schists with widespread occurrences of calc-silicate-rich rocks. The stock largely consists of hornblende-biotite quartz monzonite with localized quartz diorite and granodiorite at the margins of the intrusion. Occupying the northwest side of Tillicum Mountain and separating the pelitic schists from the intrusive rocks is a small area of amphibole-rich metavolcanic rocks, presumably belonging to the Triassic Kaslo Group (Hyndman, 1968). Correlation of rock groups in the region by Hyndman (1968) was based mainly on lithology. The same metasedimentary and metavolcanic rocks were mapped earlier by Little (1960) as belonging to the Slocan Group [Triassic and Lower Jurassic (?)] and Rossland Group (Lower Jurassic), respectively.

According to Hyndman (1968), three episodes of folding affected the metasedimentary and metavolcanic package prior to the consolidation of the intrusive stocks. Based on a detailed study at the Nemo Lakes belt to the south, Parrish (1981), recognized only two, possibly related periods of major folding Both authors, agreed that a continuity of regional metamorphism exists throughout the region with metamorphic grade generally decreasing northward. Major periods of folding and regional metamorphism were interpreted to have occurred during Jurassic time.

LOCAL GEOLOGY AND PETROGRAPHY

Figure 3 is a generalized geological map of the area that was studied in detail. Five major rock units as well as late and locally abundant lamprophyre and dacitic dykes, not shown on the map for the sake of clarity, can be recognized. Unit 1 consists of very fine to fine-grained metasedimentary rocks, including argillite, metasiltstone, and a small amount of phyllite that is locally abundant along shear zones. Where carbonaceous material is abundant, bedding, consisting of light and dark bands varying in thickness from less than a centimetre to about half a metre, can frequently be discerned. Metamorphic foliation is defined by subaligned biotite and muscovite and/or chlorite, which rarely exceed 20 per cent by volume. In many thin sections fine-grained mica shows two preferred directions of orientation at less than 30 degrees to each other, suggesting possibly two recrystallization events. Compositional layering is always parallel to one of these preferred orientations. Most of the chlorite, which replaces biotite and/or amphibole, appears to be at an angle to the compositional layering. Hornfelsed argillites in the vicinity of the southeastern quadrant of the Money Pit have randomly oriented micas and more abundant tremolite and pyrrhotite; hornfelsic argillite southwest of the Blue zone has more abundant zoisite.

Unit 2 is mainly semi-pelite with lenses, pockets, and discontinuous bands of calc-silicate rocks. The calc-silicate assemblage is typically fine to medium grained and consists dominantly of tremolite, diopside, and plagioclase with or without minor amounts of garnet, K-feldspar, zoisite, and opaque minerals. In general, the minor phases are more concentrated toward the edges of the calc-silicate bodies. Pyrrhotite is the most prominent opaque mineral observed; less common ones include sphalerite, galena, chalcopyrite, gold, marcasite, pyrite, and tetrahedrite (?).

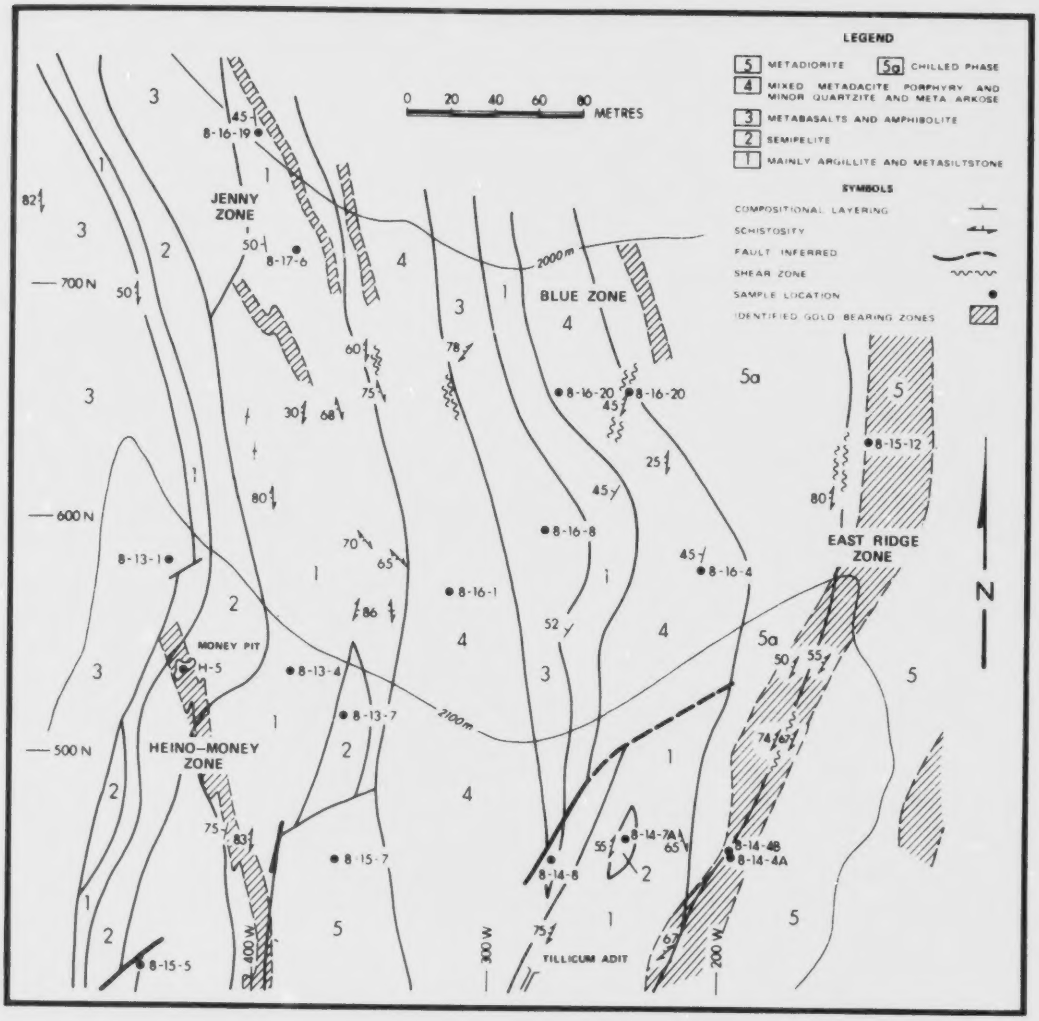

LEGEND
5 METADIORITE
5a CHILLED PHASE
4 MIXED METADACITE PORPHYRY AND MINOR QUARTZITE AND META ARKOSE
3 METABASALTS AND AMPHIBOLITE
2 SEMIPELITE
1 MAINLY ARGILLITE AND METASILTSTONE
SYMBOLS
COMPOSITIONAL LAYERING
SCHISTOSITY
FAULT INFERRED
SHEAR ZONE
SAMPLE LOCATION
IDENTIFIED GOLD BEARING ZONES
0 20 40 60 80 METRES
N
JENNY ZONE
BLUE ZONE
EAST RIDGE ZONE
MONEY PIT
HEINO–MONEY ZONE
TILLICUM ADIT
700 N
600 N
500 N
400 W
300 W
200 W
2000m
2100m
8-16-19
8-17-6
8-16-20
8-16-20
8-15-12
8-16-8
8-16-4
8-16-1
8-13-1
H-5
8-13-4
8-13-7
8-14-7A
8-14-4B
8-14-4A
8-14-8
8-15-7
8-15-5

Figure 3. Generalized geology of the area studied in detail.

Minerals identified from the fine-grained, semi-pelite matrix include subaligned biotite, tremolite, plagioclase, microcline, garnet, chlorite with or without zoisite, opaque minerals (pyrite, arsenopyrite, local pyrrhotite), and quartz. Quartz is rare in semi-pelites adjacent to calc-silicate bodies of various sizes but quartz fragments and veinlets and interstitial quartz with or without calcite sometimes occur within the calc-silicate rocks. Quartz breccia carrying gold is locally present in this unit.

Unit 3 is essentially a massive, generally porphyritic, metabasalt that is characterized by an abundance of hornblende and plagioclase with minor amounts of biotite and calcite. Recrystallization of hornblende to tremolite-actinolite, chlorite, and, locally, biotite are quite common; K-feldspar, quartz, and garnet are uncommon. This unit is locally amygdaloidal and some layers are flow brecciated. Adjacent to the metasedimentary rocks, thin interbeds of calc-silicates up to 1 centimetre thick have been observed in the metabasalt unit, indicating a gradual transition from a sedimentary-dominated to a volcanic-dominated regime (or vice versa) with intermittent quiescent periods.

Unit 4 includes fine to medium-grained, light-coloured dacite porphyry as well as localized outcrops of quartzite and meta-arkose. Plagioclase and hornblende partially replaced by chlorite are the most common phenocrysts occurring in the porphyry, whose matrix consists of K-feldspar, plagioclase, quartz, and accessory apatite and pyrite. Due to deformation and alteration, it is not possible to determine whether the dacite porphyry is an intrusive sill or a lava flow. Scattered occurrences of medium-grained, well-bedded quartzite and arkose may be large blocks of unassimilated country rock within the porphyry. Sulphides found along fractures in rocks of unit 4 are dominated by pyrite.

Unit 5 consists of medium to coarse-grained metadiorite with a fine-grained chilled margin varying from 1 to 100 metres wide. Gneissic banding is best exhibited along the finer grained contact margin in which darker hornblende-biotite bands up to 2 centimetres thick alternate with lighter coloured feldspathic bands of similar thickness. The grain size of the metadiorite increases toward the southeast and metamorphic foliation defined by subaligned biotite and poor gneissic banding is well exhibited, even in the coarsest portion of the intrusive body, which is southeast of the study area. In addition to plagioclase, hornblende, biotite, and accessory quartz, chlorite, and opaques, manganese-rich garnet is also common. Arsenopyrite, pyrite, and pyrrhotite are among the more common sulphide minerals in this unit.

Both bedding and schistosity in these units generally trend north-south. In the western half of the study area they are subvertical, whereas in the eastern portion they show gentle, generally westerly dips. The distribution pattern of the rock units suggests cross-folding with initial north-south-trending, tightly folded rocks affected by a later, open east-west-trending fold. A north-south-trending fault is also suspected in the centre of the area (Fig. 3), causing some repetition of the units. The way-up of these units is uncertain, so their relative age is not known. However, based on intrusive relationships, it is evident that units 4 and 5 are younger than units 1 through 3.

GEOCHEMISTRY AND METAMORPHIC PETROLOGY

Table 1 summarizes the major element geochemistry of 18 selected samples collected from the property. Relevant data are also plotted on the ACF

TABLE 1
MAJOR ELEMENT GEOCHEMISTRY OF SELECTED SAMPLES FROM THE TILLICUM GOLD PROPERTY

Field No.	Description	SiO_2	Al_2O_3	K_2O	Na_2O	TiO_2	MgO	Fe_2O_3	CaO	MnO	Total
8-14-4A	metadiorite	59.00	17.66	2.97	4.16	0.81	1.81	5.64	6.43	0.23	98.71
8-14-4B	metadiorite (chilled phase)	59.96	17.58	2.44	4.07	0.84	1.62	5.61	5.56	0.17	97.85
8-15-7	metadiorite	61.43	18.57	3.52	3.72	0.61	1.16	6.09	4.66	0.16	99.92
8-15-12	metadiorite	60.13	17.51	3.26	4.21	0.78	1.54	5.41	6.08	0.14	99.06
8-13-1	metabasalt	47.71	13.63	1.63	2.24	0.82	9.22	11.44	12.34	0.20	99.24
8-14-8	biotite-hornblende schist/metabasalt	52.02	17.74	3.82	1.17	0.92	4.75	10.50	8.11	0.29	99.32
8-15-5	hornfelsed basalt	47.65	16.48	4.31	1.52	0.93	6.50	11.60	7.77	0.64	97.40
8-16-1	hornfelsed basalt	49.69	16.93	3.45	2.80	1.06	6.11	11.64	6.39	0.35	98.42
8-16-8	metabasalt	46.45	14.23	3.71	1.75	0.88	6.44	12.00	10.79	0.24	96.49
8-13-4	argillite	60.64	15.56	3.95	2.64	0.67	3.01	8.62	3.09	0.13	98.30
8-16-19	graphitic argillite	58.47	15.85	1.88	2.36	0.85	1.88	3.72	5.31	0.16	90.48
8-17-6	hornfelsic argillite	55.83	16.55	3.58	2.42	0.79	3.74	9.21	4.98	0.22	97.32
8-16-4	meta-arkose	63.56	16.99	5.00	0.89	0.55	1.33	4.15	4.89	0.13	97.49
8-16-20	meta-greywacke	60.75	17.25	3.48	4.09	0.70	1.81	5.21	3.98	0.15	97.42
8-16-21	muscovite phyllite	65.38	17.35	5.44	0.36	0.56	1.30	5.14	0.83	0.19	96.55
8-13-7	calc-silicate schist	55.29	16.15	4.92	1.31	0.97	3.36	8.85	6.88	0.26	97.99
8-14-7A	calc-silicate schist	50.57	15.87	5.51	0.47	0.85	5.17	10.88	8.49	0.32	98.13
H-5	calc-silicate skarn (massive)	47.14	12.13	3.18	0.52	0.81	8.16	11.43	13.14	0.90	97.41

*Total iron expressed as Fe_2O_3

diagram (Fig. 4) which shows the compositional fields of various volcanic metasedimentary material, as well as the prograde and retrograde mineral assemblages observed in these and other samples collected from the study area. When plotted on an A'FK diagram, most of these rocks fall on or close to the FK joint with a concentration near the composition of biotite. The only exception is a highly sericitized dacite, which lies along the muscovite-biotite joint toward the composition of muscovite. The high potassium content accounts for the absence of pure aluminum-silicate phases, while the stabilization of micas probably hinders the crystallization of staurolite and chloritoid. Nevertheless, the prograde mineral assemblages are compatible with an almandine-staurolite facies of regional metamorphism, whereas the retrograde assemblages indicate the albite-epidote-chlorite-actinolite subfacies of greenschist metamorphism.

The metamorphic history of the area is complex. It was generally assumed that the hornfelsic texture so evident in many argillites, particularly those in the vicinity of the Money Pit, was due to the intrusion of the Goatcanyon-Halifax Creeks stock (for example, Kwong and Addie, 1982). However, with recognition of the metadiorite and more detailed mapping and examination of drill cores during the summer of 1983, a more complex picture is evident. Spatially, hornfelsic argillites, with the exception

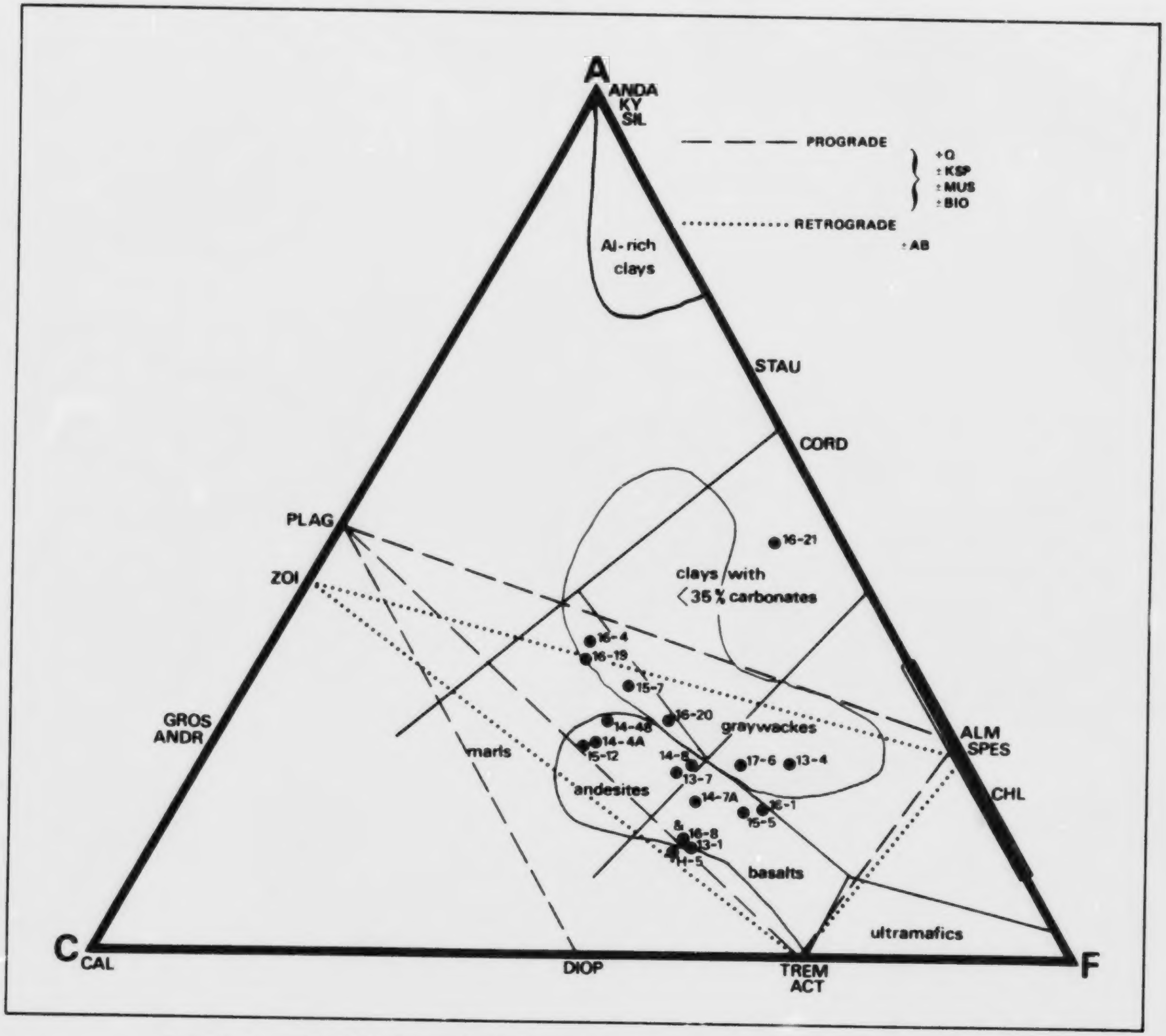

A
ANDA
KY
SIL
PROGRADE
RETROGRADE
+Q
±KSP
±MUS
±BIO
±AB
Al-rich
clays
STAU
CORD
PLAG
ZOI
GROS
ANDR
16-21
clays with
<35% carbonates
16-4
16-19
15-7
16-20
graywackes
14-4B
14-4A
15-12
14-8
13-7
17-6
13-4
marls
andesites
14-7A
16-1
15-5
&
16-8
13-1
14-5
basalts
ALM
SPES
CHL
ultramafics
C
CAL
DIOP
TREM
ACT
F

Figure 4. ACF plot for selected samples from the Tillicum gold property showing prograde and retrograde assemblages.

of those characterized by abundant zoisite, correlate more closely with the metadiorite than with the younger stock. As well, textural evidence supports the hypothesis that an early generation of hornfels formed during intrusion of the diorite. Contact metamorphism of carbonate lenses, pockets, and bands produced a diopside-dominated rock, randomly oriented fine-grained biotite grew in the argillaceous sediments, and hornblende in some metabasalt was recrystallized to actinolite. During subsequent regional metamorphism, recrystallization in these partially dehydrated rocks was generally less pervasive than elsewhere and the effects of structural deformation are more obvious. The most prominent effects were development of subaligned micas and growth of accessory manganese-rich garnets in the finer grained rocks, and the development of poor banding in the diorite. The conversion of carbonates to calc-silicates involves a reduction in volume and any incipient porosity produced during the early hornfelsing was probably accentuated by structural deformation during the regional metamorphism. This probably accounts for the brecciated texture of calc-silicate pockets in the Money Pit.

During intrusion of the Goatcanyon-Halifax Creeks stock, a third period of recrystallization was initiated. Diopside in the calc-silicate bodies was replaced by tremolite, calcite, and quartz; a second generation of actinolite grew in the metabasalt; and along microfractures in the metasedimentary rocks, amphibole, biotite, garnet, and plagioclase were replaced by chlorite, a new biotite, and zoisite. Sulphides were also modified; pyrrhotite was replaced by marcasite and arsenopyrite was introduced. If the intrusion of the Goatcanyon-Halifax Creeks stock occurred after the stratigraphic succession was uplifted or partially uplifted, then the effects of this second contact metamorphism would be very difficult, if not impossible, to distinguish from those of retrograde metamorphism except in the immediate vicinity of the intrusion. It is likely that retrogressive reactions were enhanced by this younger intrusion, which provided heat and a ready source for reactive fluid. In short, a three-stage model of modification of the rocks in the study area explains the observed textures and field data better than the two-stage model proposed earlier (Kwong and Addie, 1982).

PRECIOUS METAL AND SULPHIDE MINERALIZATION

Within the mapped area, gold is the main commodity of interest. it occurs essentially in its native state as fracture-filling material. It commonly occurs in veinlets and as discontinuous trains of tiny blebs (less than 0.1 millimetre in diameter) along microfactures in various rock types; rarely it occurs as impregnations and stringers up to 0.5 centimetre in width in brecciated calc-silicate rock and quartzite, and, to a lesser degree, semi-pelite. From polished section studies, it is evident that the deposition of gold covered a rather wide range of temperatures. Plate I shows native gold associated with pyrrhotite,

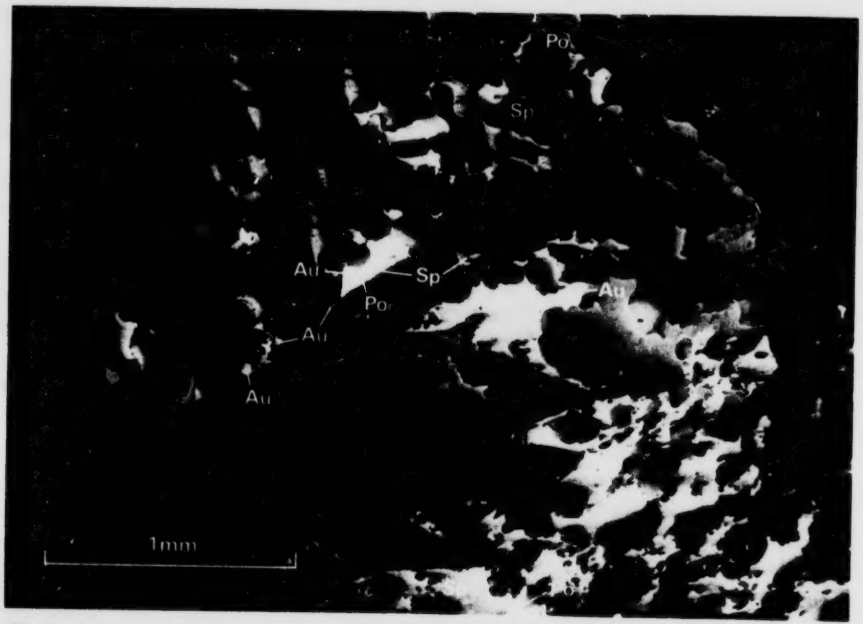


Plate I. Native gold (Au), pyrrhotite (Po), and sphalerite (Sp), with or without tetrahedrite, fill the interstitial spaces between tremolite crystals and partially resorbed, rounded grains of diopside. (Specimen collected from the Money Pit).

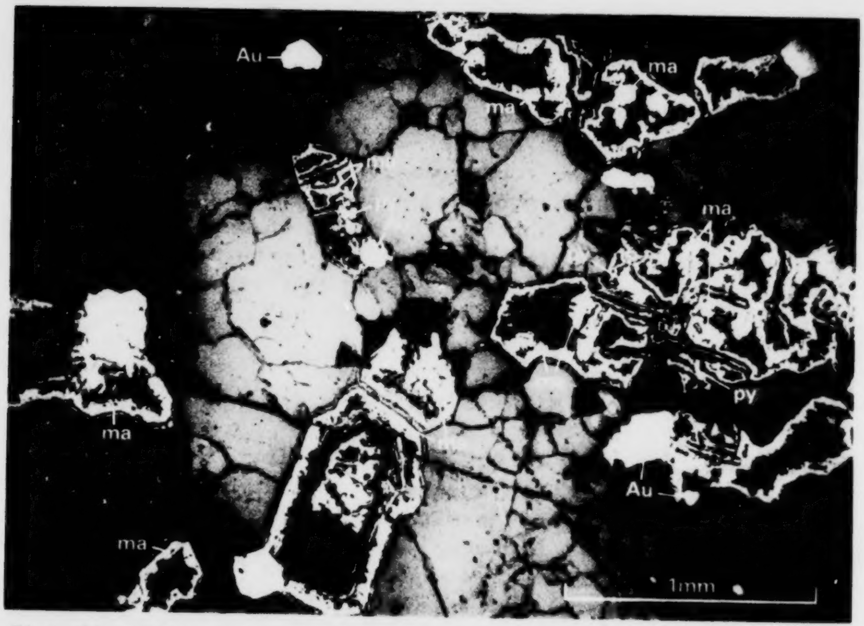


Plate II. Native gold (Au) is associated with marcasite (ma) and locally pyrite (py) that have almost completely replaced pyrrhotite (Po). (Specimen collected from the Heino Pit by G. G. Addie).

sphalerite, and possibly tetrahedrite filling the interstitial spaces between tremolite crystals and partly resorbed, rounded diopside grains. More rarely, gold lies along cleavage planes in the amphibole. At higher magnification, sphalerite shows exsolved trains of pyrrhotite and chalcopyrite, suggesting a moderately high temperature of deposition of the original sphalerite solid solution; a temperature of 350 50 degrees Celsius for the precipitation of gold is compatible with the observed mineral associations. Plate II shows blebs of gold associated with marcasite which forms under low temperature (probably <250 degrees Celsius) acidic conditions. Plate III shows a discontinuous train of blebs of native gold crossing pyrrhotite and pyrite. The temperature of deposition of this gold is uncertain but is probably low (<150 degrees Celsius ?) because the gold postdates all other minerals observed in the section. Rarely, gold also occurs as globules up to 1 millimetre in diameter along weathered surfaces of some semi-pelites in the vicinity of Heino Pit. Its shape suggests that this gold is pseudomorphing goethite with which it is closely associated. Apparently, during oxidation of iron sulphides to goethite, gold associated with the sulphides agglomerates and remains fixed *in situ* rather than being removed. Hence, secondary dispersal of the precious metal during weathering is probably minimal in this area.

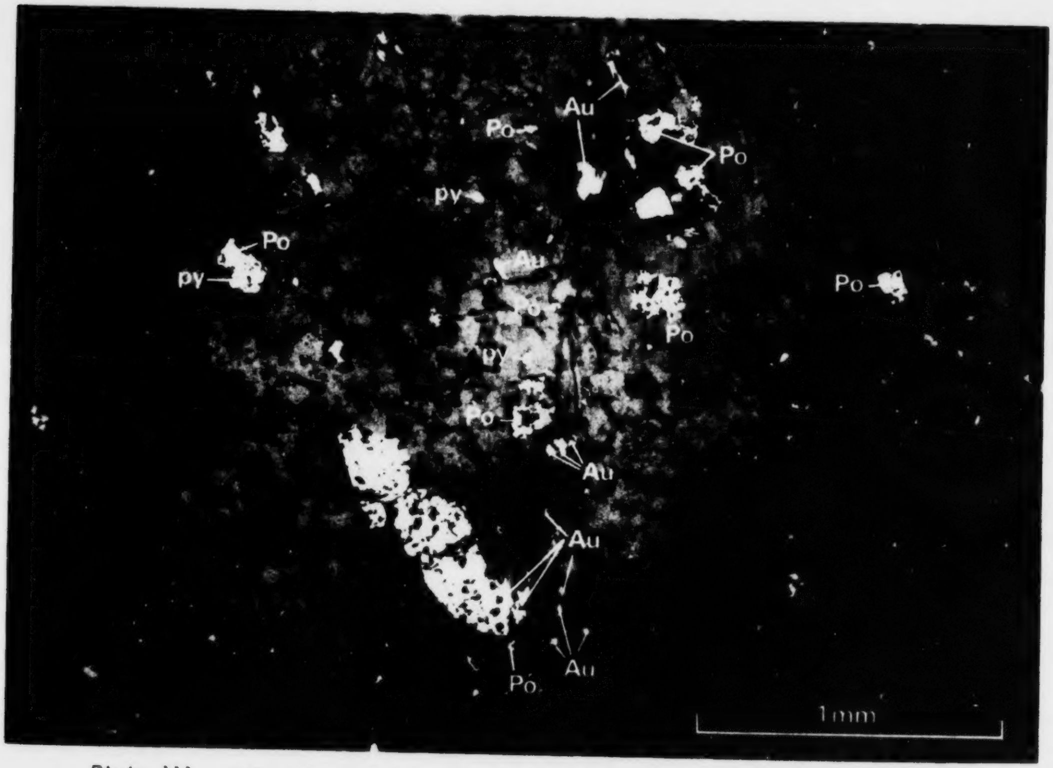


Plate III. Late-stage native gold (au) forms a discontinuous train of blebs along a fracture that cuts pyrrhotite (Po) and pyrite (py). (Specimen collected from the vicinity of the Heino Pit by G. G. Addie).

Mineralization also deposited sphalerite, galena, pyrrhotite, pyrite, marcasite, arsenopyrite, chalcopyrite, and tetrahedrite (?). Pyrrhotite and, to a lesser degree, pyrite are the most common disseminated sulphides in all rock units except the metabasalt. Pyrrhotite also occurs with sphalerite and galena as impregnations in locally brecciated rocks. Tetrahedrite (?) occurs mainly as a minor phase associated with impregnations of sulphides with or without gold. Chalcopyrite, another minor phase, occurs mainly as veinlets and exsolved lamellae in sphalerite. Arsenopyrite occurs rarely in the metadiorite but is locally abundant in the metasedimentary rocks. It postdates pyrrhotite, pyrite (except along late fractures), sphalerite, and galena but does not replace them. In contrast, marcasite is solely a replacement product of pyrrhotite. Upon weathering, arsenopyrite is locally altered to scorodite, while native sulphur is a frequent alteration product of marcasite. Other prominent weathering products observed in shear zones of the gold-rich Money Pit include goethite, hydrozincite, hemimorphite, gypsum, and calcite.

Besides mineralogy and modes of occurrence of the ore minerals, the most important parameter for establishing a genetic model for the gold mineralizaiton is the distribution of identified gold-bearing zones. As is evident from Figure 2, nearly all the proven gold zones are roughly north-south trending, although locally offset by later minor faults. In addition, they are not limited to a particular lithology but transect all rock types. Therefore, notwithstanding the possibility that there might be a lithological control on the primary distribution of the ore elements, their final concentration is more likely structurally controlled.

DISCUSSION AND CONCLUSION

To date, lithological similarity has been the main criterion employed in making regional correlations of rocks in the Tillicum Mountain area with those elsewhere. There is some controversy regarding the assignment of the metasedimentary rocks and the fringing patch of amphibolite (metabasalt). Thus, Little (1960) assigned the metasedimentary rocks to the Slocan Group (Triassic to Lower Jurassic) and the metabasalts to the Rossland Group (Lower Jurassic), whereas Hyndman (1968) assigned them to the Milford Group [Pennsylvanian (?) to Triassic] and the Kaslo Group (Triassic), respectively. The present study confirms a significant igneous component in the country rock assemblage. Moreover, it is shown that the transition between the metasedimentary rocks, which are often tuffaceous in appearance, and the metabasalt is gradual. The author believes that the entire rock assemblage in the area belong to the Kaslo Group since they show remarkable similarity to the rocks described by Cairnes (1934, pp. 43-48).

Any model for the gold mineralization has to account for the following observations: (a) gold occurs mainly as fracture fillings; (b) its distribution appears to be primarily structurally controlled; (c) its deposition covers a wide temperature range; and (d) at some stage of the mineralization, the process involved an acidic solution which also provided a source of sulphur for various sulphidation reactions resulting in the formation of arsenopyrite and marcasite. Furthermore, the location of the gold-rich Money-Heino zone with respect to the silver-gold occurrences in Arnie Flats to the south and the silver-dominated Silver Queen mine to the southeast (Fig. 2) indicate that the gold/silver ratio increases northwestward, roughly in accordance with a decreasing grade of regional metamorphism. A model consisting of the following stages is proposed:

(1) Intrusion of a dioritic laccolith into Triassic sedimentary, volcanic, and volcaniclastic rocks with the production of a first generation of hornfels and introduction of incipient porosity into carbonate-rich layers as a result of devolatilization reactions. At this stage, pyrrhotite is the stable form of iron sulphide adjacent to the intrusion.

(2) Regional metamorphism during Jurassic time of the igneous-sedimentary package producing prograde staurolite-almandine facies assemblages; the associated regional deformation gave rise to a metamorphic foliation. The incipient porosity in the calc-silicate-rich layers was accentuated and metamorphic differentiation resulted in remobilization of finely dispersed gold in the direction of decreasing temperature gradient.

(3) Intrusion of the Goatcanyon-Halifax Creeks stock in Late Jurassic or Early Cretaceous time with associated structural deformation led to a third episode of recrystallization. This modified former metamorphic fabrics and was accompanied by gold mineralization. Presumably acidic hydrothermal solutions emanating from the stock, which may or may not contain additional gold, mobilized the gold and redeposition occurred along favourable sites. The initial deposition occurred in response to pH changes when the solution reacted with calc-silicate assemblages; the temperature was high enough that pyrrhotite remained the prevalent iron sulphide species. Later deposition, however, was caused by a decrease in temperature and the mineralization took place in other host rocks. The introduction of arsenopyrite followed by the replacement of pyrrhotite by marcasite are part of the same mineralization process but occurred at lower temperatures.

In conclusion, gold mineralization observed in the Tillicum Mountain property is mainly epigenetic and mesothermal with the temperature of deposition extending to a lower regime during cooling of the Goatcanyon-Halifax Creeks stock. Whereas the source of gold remains uncertain, there is evidence of metamorphic differentiation affecting gold/silver ratio in the country rocks so that at least part of the precious metal may represent remobilized material concentrated in a convection cell set up by the Jurassic/Cretaceous Goatcanyon-Halifax Creeks stock. Thus, lower grade rocks around the southern and southeastern margins of the stock are favourable sites for gold mineralization whereas higher grade rocks toward Snow Creek are more likely hosts for silver mineralization. Furthermore, if the rock assemblage in the Tillicum Mountain area belongs to the Kaslo series as suggested, then similar rocks along the northwestern corner of the stock may be favourable targets for further exploration.

ACKNOWLEDGMENTS

I would like to thank the Esperanza-La Teko crew for their hospitality during my short stay in the property in the summer of 1983. Critical comments from Drs. T. Hoy, W. M. Johnson, and G. E. Ray of the British Columbia Ministry of Energy, Mines and Petroleum Resources have greatly improved an earlier version of this paper.

REFERENCES

Cairnes, C. E. (1934): Slocan Mining Camp, British Columbia, *Geol. Surv., Canada,* Mem. 173.

Hyndman, D. W. (1968): Petrology and Structure of the Nakusp Map-area, British Columbia, *Geol. Surv., Canada,* Bull. 161.

Kwong, Y.T.J. and Addie, G. G. (1982): Tillicum Mountain Gold Prospect, *B.C. Ministry of Energy, Mines & Pet. Res.,* Geological Fieldwork, 1981, Paper 1982-1, pp. 38-45.

Little, H. W. (1960): Nelson Map-area, West Half, British Columbia, *Geol. Surv., Canada,* Mem. 308.

Parrish, R. R. (1981): Geology of the Nemo Lakes Belt, Northern Valhalla Range, Southeast British Columbia, *Cdn. Jour. Earth Sci.,* Vol. 18, pp. 944-958.

Smith, F. M. (1983): Gold Porphyrites: A Model for Gold Deposits Related to Subaqueous Flows, *GAC-MAC-CGU,* Joint Annual Meeting, Program with Abstracts, Victoria, May 11-13, 1983, p. A62.

Winkler, H.G.F. (1965): Petrogenesis of Metamorphic Rocks, *Spinger-Verlag,* New York.

TILLICUM MOUNTAIN GOLD-SILVER PROJECT
(82F/13, 82K/4)

By G. E. Ray
Ministry of Energy, Mines and Petroleum Resources
and
J. McClintock and W. Roberts
Esperanza Explorations Ltd.

INTRODUCTION

The Tillicum Mountain gold-silver property lies approximately 13 kilometres east of Burton and 30 kilometres south of Nakusp in southeastern British Columbia (Fig. 5). Publications relevant to this area include those by Cairnes (1934), Little (1960), Hyndman (1968), Parrish (1981), Kwong and Addie (1982), Roberts and McClintock (1984), McClintock and Roberts (1984), and Kwong (this volume).

Current exploration was initiated in 1980 after visible gold was discovered in the area by two local prospectors, Elaine and Arnold Gustafson. In 1982 Esperanza Explorations Ltd. and La Teko Resources Ltd. concluded a joint venture agreement to assess the property; a 1.5-million dollar exploration program of soil sampling, trenching, and drilling was completed in 1983. Seven prominent gold-bearing, skarn-like zones were outlined, namely the Heino-Money, East Ridge, Jenny, 950, Grizzly, South Slope, and Ridge Road zones. In addition, extensive silver geochemical soil anomalies were discovered in the vicinity of the defunct Silver Queen mine and over the 'Silver Jack' zone on Arnies Flats, approximately 2 kilometres southeast and 1.5 kilometres southwest of Tillicum Mountain respectively (Fig. 5). The 1983 drill program on the Heino-Money zone, situated 200 metres north of Tillicum Mountain, outlined a 1 to 7-metre-thick gold-bearing skarn horizon with a strike length of 150 metres and a depth of 60 metres. This zone currently comprises a 36 000-tonne orebody grading 20.5 grams gold per tonne (Roberts and McClintock, 1984).

During 1984, work by Esperanza Explorations Ltd. included driving a 60-metre adit into the upper part of the Heino-Money zone for both exploration and bulk sampling purposes. In addition, approximately 4 kilometres of new roads were constructed to the Silver Queen mine and Silver Jack areas, and the collapsed Silver Queen mine adit was reopened, sampled, and mapped by company geologists. Twelve drill holes were put down in the Silver Queen mine area, and the Silver Jack zone (Fig. 5) was trenched and mapped.

During the summer of 1984, the Geological Branch of the British Columbia Ministry of Energy, Mines and Petroleum Resources, in cooperation with Esperanza Explorations Ltd., completed a three-week geological mapping

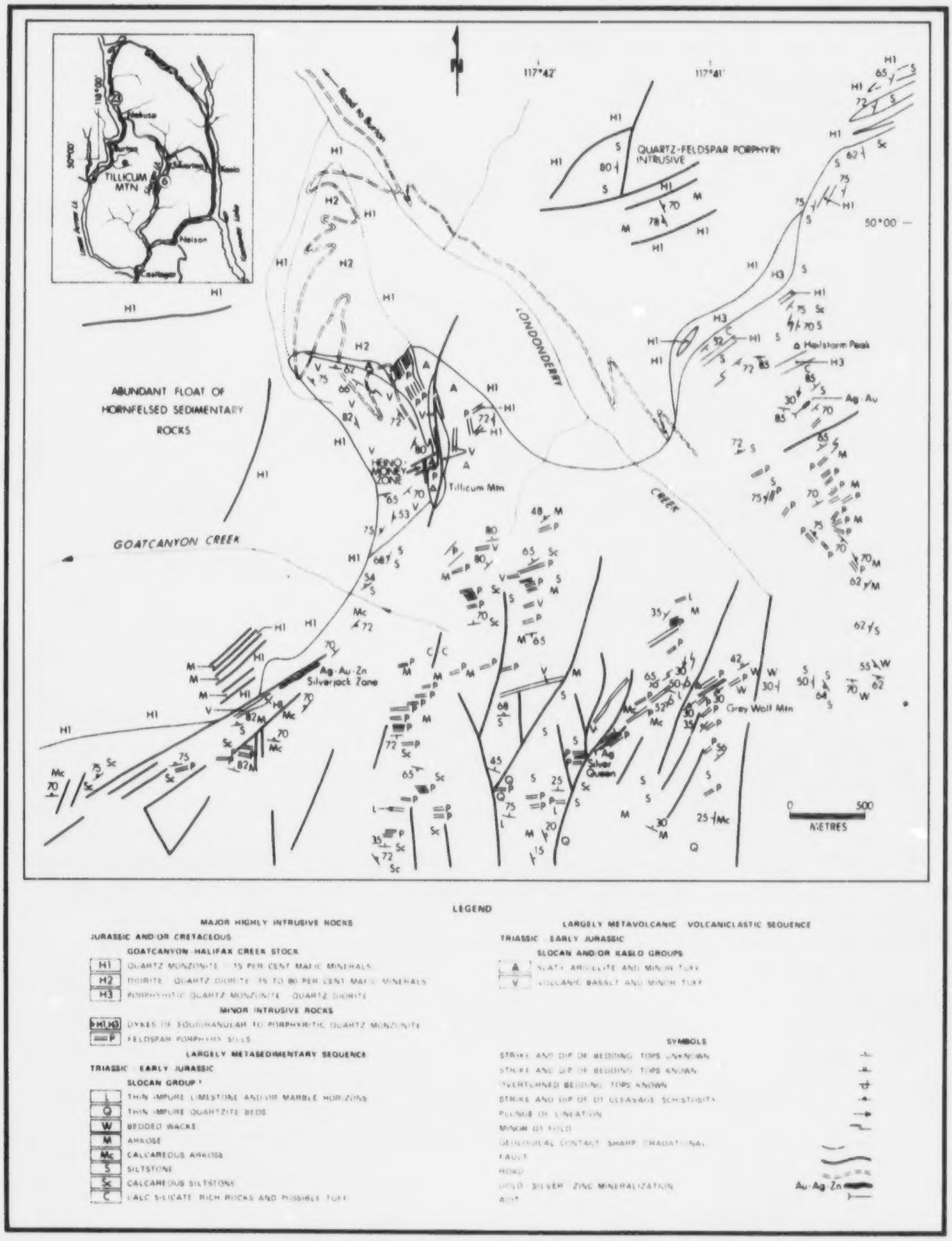

TILLICUM MTN
Nelson
Castlegar
Nakusp
Burton
Kaslo
117°42'
117°41'
50°00'
QUARTZ-FELDSPAR PORPHYRY INTRUSIVE
Road to Burton
LONDONDERRY CREEK
GOATCANYON CREEK
ABUNDANT FLOAT OF HORNFELSED SEDIMENTARY ROCKS
HEINO-MONEY ZONE
Tillicum Mtn
Hailstorm Peak
Ag-Au
Ag-Au-Zn Silverjack Zone
Ag Silver Queen
Grey Wolf Mtn
0
500
METRES
LEGEND
MAJOR HIGHLY INTRUSIVE ROCKS
JURASSIC AND/OR CRETACEOUS
GOATCANYON-HALIFAX CREEK STOCK
H1 QUARTZ MONZONITE < 15 PER CENT MAFIC MINERALS
H2 DIORITE - QUARTZ DIORITE 15 TO 80 PER CENT MAFIC MINERALS
H3 PORPHYRITIC QUARTZ MONZONITE - QUARTZ DIORITE
MINOR INTRUSIVE ROCKS
H1,H3 DYKES OF EQUIGRANULAR TO PORPHYRITIC QUARTZ MONZONITE
P FELDSPAR PORPHYRY SILLS
LARGELY METASEDIMENTARY SEQUENCE
TRIASSIC - EARLY JURASSIC
SLOCAN GROUP ?
L THIN IMPURE LIMESTONE AND/OR MARBLE HORIZONS
Q THIN IMPURE QUARTZITE BEDS
W BEDDED WACKE
M ARKOSE
Mc CALCAREOUS ARKOSE
S SILTSTONE
Sc CALCAREOUS SILTSTONE
C CALC-SILICATE RICH ROCKS AND POSSIBLE TUFF
LARGELY METAVOLCANIC - VOLCANICLASTIC SEQUENCE
TRIASSIC - EARLY JURASSIC
SLOCAN AND/OR KASLO GROUPS
A SLATY ARGILLITE AND MINOR TUFF
V VOLCANIC BASALT AND MINOR TUFF
SYMBOLS
STRIKE AND DIP OF BEDDING, TOPS UNKNOWN
STRIKE AND DIP OF BEDDING, TOPS KNOWN
OVERTURNED BEDDING, TOPS KNOWN
STRIKE AND DIP OF D1 CLEAVAGE/SCHISTOSITY
PLUNGE OF LINEATION
MINOR D1 FOLD
GEOLOGICAL CONTACT: SHARP, GRADATIONAL
FAULT
ROAD
GOLD - SILVER - ZINC MINERALIZATION
Au-Ag-Zn
ADIT

Figure 5. Simplified geology of the Tillicum-Grey Wolf Mountains area.

and sampling program in the area. This work involved mapping, at 1:5000 scale, a 25-square kilometre area in the Tillicum Mountain-Grey Wolf Mountain-Hailstorm Peak area (Fig. 5). Two drill holes intersecting the gold-rich Heino-Money zone (hole TM 82-16) and the silver-rich Silver Queen mine zone (hole SQ 84-10) were systematically sampled. These core samples will be analysed for their major and trace element contents to determine whether any element zoning patterns or enrichment halos are associated with the mineralization. In addition, a suite of unmineralized mafic metavolcanic rocks and economically important feldspar porphyry sills were sampled; these will be subjected to whole rock analysis. Samples of some impure limestone beds in the Silver Queen mine vicinity will be analysed for microfossils.

REGIONAL GEOLOGY

The rocks hosting gold-silver mineralization in the Tillicum Mountain area lie within the easterly trending Nemo Lakes belt (Parrish, 1981), a 5-kilometre-wide roof pendant largely comprising a sequence of metasedimentary and metavolcanic rocks. To the north and west (Fig. 5), the belt is intruded by the Goatcanyon-Halifax Creeks stock of Jurassic and/or Cretaceous age (Hyndman, 1968), while to the south it is invaded by the Nemo Lakes quartz monzonite stock of Eocene age (Parrish, 1981). The Goatcanyon-Halifax Creeks stock is also largely of quartz monzonite composition (Hyndman, 1968); however, near Tillicum Mountain contamination by mafic volcanic rocks of the belt resulted in the local formation of hybrid quartz diorite and mafic diorite zones within the stock.

Supracrustal rocks of the Nemo Lake belt in the Tillicum Mountain-Grey Wolf Mountain-Hailstorm Peak area (Fig. 5) are dominated by metamorphosed siltstone, calcareous siltstone, arkose, and wacke, with lesser amounts of mafic volcanic rock, tuff, argillite, and some impure carbonate layers. The age, stratigraphy, and structure of the supracrustal rocks is uncertain. Little (1960) included them in the Triassic to Early Jurassic (?) Slocan Group. However, Hyndman (1968) split the section, placing the basic volcanic rocks on the northern slopes of Tillicum Mountain (Fig. 5) into the Triassic Kaslo Group, and the remaining metasedimentary rocks into the Pennsylvanian to Triassic Milford Group.

The supracrustal rocks have undergone a post-Early Jurassic phase of regional metamorphism and folding (Hyndman, 1968; Parrish, 1981) that predates the Middle to Late Jurassic intrusion of the granitoid stocks (Read and Wheeler, 1976). This event resulted in sillimanite grade metamorphism throughout most of the Nemo Lakes belt (Parrish, 1981); however, the grade was lower around Tillicum Mountain and resulted in the formation of biotite-muscovite-chlorite and amphibole. In addition to the regional metamorphism, the rocks have locally been subjected to at least two episodes of contact metamorphism. The first either preceded or accompanied the regional deformation and is associated with swarms of feldspar porphyry sills that may be spatially and genetically related to some of the gold-silver mineralization in the district. The second hornfelsing postdates the regional deformation and is related to intrusion of the large granitoid stocks. The area also contains swarms of late lamprophyre dykes that cut both the supracrustal rocks and the Goatcanyon-Halifax Creeks stock.

GEOLOGY OF THE TILLICUM MOUNTAIN AREA

The simplified geology of the area between Tillicum Mountain, Arnies Flats, Grey Wolf Mountain, and Hailstorm Peak is shown on Figure 5. The northern part of the area is underlain by coarse-grained plutonic rocks of the Goatcanyon-Halifax Creeks stock; the southern portion is largely occupied by a highly deformed sequence of metasedimentary rocks. A small area of mafic metavolcanic rocks occupies an embayment adjacent to the Goatcanyon-Halifax Creeks stock, immediately north of Tillicum Mountain (Fig. 5).

GOATCANYON-HALIFAX CREEKS STOCK (UNIT H)

This stock, which is Jurassic and/or Cretaceous in age (Hyndman, 1968), is largely of quartz monzonite composition (unit H1). It generally contains between 3 and 10 per cent mafic minerals which mainly comprise biotite with sporadic hornblende. Southwest of Londonderry Creek (Fig. 5), the stock includes a 200 to 700-metre-wide, northerly trending zone of highly mafic diorite and quartz diorite (unit H2) containing between 15 and 80 per cent hornblende. This rock probably represents hybridized country rock in the stock since the unit lies on strike with a belt of mafic volcanic rocks that underlies the northern slopes of Tillicum Mountain. In thin section phenocrysts of hornblende up to 0.5 centimetre in length are observed; these contain pale brown cores and dark green margins. Minor amounts of chloritized, deformed biotite are present, and the unaltered, fresh matrix largely comprises hornblende and plagioclase (An_{36-42}). Minor to trace amounts of quartz, epidote, sphene, apatite, and carbonate are also present.

The third rock type identified within the Goatcanyon-Halifax Creeks stock is a distinctive, porphyritic biotite-hornblende granodiorite (unit H3) that contains up to 15 per cent mafic minerals; the rock is characterized by feldspar phenocrysts up to 2 centimetres in diameter. This unit occurs along the margins of the stock east of Londonderry Creek and north of Hailstorm Peak (Fig. 5). An 80-metre-wide dyke of this unit also intrudes metasedimentary rocks immediately south of Hailstorm Peak (Fig. 5).

The margins of the stock generally show no decrease in grain size, but immediately east of Londonderry Creek, the marginal phase of the quartz monzonite contains abundant xenoliths. The contact with the country rock is generally poorly exposed and is locally faulted. North of Hailstorm

Peak, however, a clear intrusive relationship is seen; dykes, sills, and stringers of xenolith-bearing, biotite granodiorite become more numerous, and the hornfelsing increases as the main stock is approached. Country rocks adjacent to the stock are recrystallized and often silicified, and many of the calcareous metasedimentary rocks have undergone weak skarn alteration. Screens and xenoliths are generally rare in the stock, but some relatively large, apparently fault-bounded units of country rock occur west of Arnies Flats, northwest of Hailstorm Peak, and west of Tillicum Mountain (Fig. 5). These areas are poorly exposed but contain abundant float of highly hornfelsed, granitized metasedimentary rocks derived from arkosic and calcareous sediments.

METAVOLCANIC ROCKS (UNIT V)

This unit comprises an interlayered, highly deformed sequence of metamorphosed basalt, mafic tuff, and volcanic breccia, together with some argillite. It is largely confined to an area northwest of Tillicum Mountain where it forms an arcuate, apparently folded unit over 500 metres in outcrop width. Minor amounts of mafic volcanic rock immediately adjacent to the faulted margin of the Goatcanyon-Halifax Creeks stock, southwest of the Silver Jack mineral zone (Fig. 5), may represent part of this unit.

The metabasalts are massive to weakly layered to schistose; they comprise hornblende and calcic plagioclase with lesser amounts of biotite, chlorite, tremolite-actinolite, and carbonate. Some flows are characterized by flow brecciated margins and deformed, feldspar-filled amygdales up to 0.5 centimetre in diameter. The tuffs and coarse volcaniclastic rocks locally contain coarse hornblende crystals that can exceed 1.5 centimetres in diameter, and in most cases the clasts are highly deformed and stretched.

A few, thin mafic volcanic flows are present within the main metasedimentary sequence throughout the district. Two of these flows are seen north and northwest of the Silver Queen mine adit and each is traceable for over 300 metres along strike (Fig. 5). Both display amydaloidal tops (?) on their northwestern margins; they may form part of a single flow that has been displaced by faulting.

METASEDIMENTARY ROCKS

Metasedimentary rocks underlie most of the southern and southeastern part of the area (Fig. 5). They comprise an interfolded, interlayered succession of mainly siltstone, arkose, and wacke with local calc-silicate-rich layers. Rare, thin beds of dolomitic limestone, marble, and impure quartzite are locally developed: the calcareous siltstone (unit Sc) and calcareous arkose (unit Mc) beds contain variable amounts of calc-silicate minerals. Argillites are relatively rare in the sequence; most outcrop north of Tillicum Mountain where they are intimately associated with the mafic volcanic and volcaniclastic rocks (unit V). The slaty argillities (unit A) are generally very poorly bedded; they consist mainly of chlorite, biotite, quartz, feldspar, and tremolite with variable amounts of pyrite. Some argillites contain thin, discontinuous beds of siltstone and calc-silicate rock.

No marker horizons are recongized in the metasedimentary rocks. This, together with rapid lateral and vertical changes in lithology and the complex deformation, makes it difficult to outline lithological boundaries between the various metasedimentary rock units. Despite the deformation and metamorphism, however, sedimentary structures, including graded bedding, are locally preserved.

The siltstones (unit S) are massive to well-bedded, fine to medium-grained rocks that generally contain biotite, sericite, and chlorite totalling more than 8 per cent by volume. The arkoses (unit M) are generally leucocratic, feldspathic rocks that vary from massive to poorly bedded to weakly schistose. These generally carry biotite and sericite totalling less than 8 per cent by volume. Turbiditic wackes (unit W) are well developed in the vicinity of Grey Wolf Mountain where they display graded bedding, rare crossbedding, and some slump structures. The calc-silicate-rich sedimentary rocks are often massive, medium to coarse grained, and recrystallized. However, remnant bedding is locally preserved, together with coarse clastic horizons that may represent reworked volcaniclastic material. The calc-silicate-rich rocks contain tremolite-actinolite, clinozoisite, epidote, carbonate, and some diopside.

In a few localities, the supracrustal sequence contains thin beds of dolomitic limestone and marble (unit L), and impure quartzite (unit Q) that are interbedded with either wacke or siltstone. Individual beds seldom exceed 1 metre in thickness and many measure less than 3 centimetres. Coarse-grained, recrystallized, and deformed dolomitic marble beds crop out west and southwest of Grey Wolf Mountain, and some skarn-altered, mineralized calcareous horizons and marble beds are seen in the vicinity of the defunct Silver Queen mine (Fig. 5).

LESSER INTRUSIVE ROCKS

These are divisible into four main suites, namely: feldspar porphyries (unit P) that have been affected by the regional deformation and metamorphism; granodiorite sills (unit H1) that are related to the Goatcanyon-Halifax Creeks stock; aplitic dykes that cut the stock and probably represent a late phase of its intrusion; and swarms of late stage lamprophyre dykes that appear to be the youngest intrusions in the district. Due to their small dimensions the aplites and lamprophyres are not shown on Figure 5.

The feldspar porphyries (unit P), which occur as sill-like bodies varying from 1 to over 100 metres in width, tend to concentrate in swarms. They may have economic significance because the skarn alteration and mineralization in both the Heino-Money zone and the Silver Queen mine area are spatially, and possibly genetically, related to these sills. Originally, company geologists considered these rocks to represent felsic volcanic flows, but rare crosscutting intrusive features and xenoliths are seen, and the sills are widely distributed throughout the district. These rocks are generally of diorite to quartz diorite composition; they are leucocratic and are characterized by abundant plagioclase phenocrysts up to 1 centimetre in diameter. Biotite generally forms less than 10 per cent by volume and is the commonest and most widespread mafic mineral; however, some rarer, more mafic sills contain appreciable quantities of hornblende.

Igneous textures and euhedral feldspar phenocrystals are seen in the central portions of the larger sills but the margins are often schistose with highly flattened feldspar crystals. In thin section the margins of the oligoclase phenocrysts are often recrystallized, being rimmed with small crystals of fresh untwinned plagioclase. In many areas this recrystallization process is complete and the phenocrysts are pseudomorphed by a mosaic of small plagioclase crystals, each less than 0.1 millimetre in diameter. The fine-grained matrix mainly comprises plagioclase and random to subaligned flakes of biotite; there are minor to trace amounts of quartz, hornblende, chlorite, and sulphides. Country rocks immediately adjacent to the feldspar porphyry sills are often weakly hornfelsed, and at many localities throughout the district the sills are spatially associated with calc-silicate skarn alteration which is geochemically anomalous in gold and silver.

Granodiorite to quartz monzonite sills and dykes (unit H1) related to the Goatcanyon-Halifax Creeks stock are up to 50 metres thick; most are found within 300 metres of the main stock margin. They are generally leucocratic and locally contain abundant xenoliths of country rock. Most sills are biotite bearing, but southwest of the Silver Jack zone (Fig. 5) one 200-metre-long sill contains up to 25 per cent hornblende and biotite.

Aplite or alaskite dykes and sills, mostly less than 2 metres wide, are common in the area; they cut both the Goatcanyon-Halifax Creeks stock and the surrounding country rocks. The leucocratic sills have sharp margins and are white to grey in colour. Some bodies contain round quartz phenocrysts up to 3 millimetres in diameter; a few of the larger dykes also contain some biotite and hornblende phenocrysts. These rocks appear to represent a late phase of the Goatcanyon-Halifax Creeks stock.

Lamprophyre dykes up to 15 metres in width are common in the district. They have sharp margins and generally occur in swarms that follow pre-existing, northerly to northeasterly trending fault zones. In outcrop they form dark, medium to coarse-grained, massively textured rocks that carry coarse crystals of biotite, amphibole, and possibly pyroxene. It is likely that several different mineralogical lamprophyre suites are present in the area. In rare instances these rocks exhibit compositional layering parallel to the dyke margins, and the central portions of some bodies carry either rounded feldspathic clots up to 5 centimetres in diameter or vague, diffuse, mafic xenoliths. A narrow lamprophyre sill in the Silver Queen mine area consists predominantly of highly clouded feldspar laths up to 1 millimetre in length. Biotite makes up 15 per cent by volume and forms weakly chloritized, randomly oriented crystals up to 0.5 millimetre long. Large pseudomorphs after phenocrysts of amphibole or pyroxene are entirely replaced by chlorite, and the rocks contain small, rounded quartz-filled amygdales (?). The groundmass carries trace amounts of tremolite-actinolite, quartz, carbonate, and sulphides.

STRUCTURAL HISTORY OF THE TILLICUM MOUNTAIN AREA

A postulated history of events in the area is shown in Table 1. Minor folds and reliable bedding-cleavage intersections are rare in the district. Nevertheless, two episodes of regional deformation are recognized; these are tentatively correlated with the two structural phases outlined in the Nemo Lakes belt further east (Parrish, 1981). The earliest (D1) produced large-scale folds with an associated axial planar cleavage-schistosity. Fold axes, as measured from the rare bedding-cleavage intersection lineations, now plunge approximately 30 degrees in a southwest to south-southwest direction. Younging directions recorded from both graded and current bedding are mostly vague and uncertain. However one fault-bounded panel west of Grey Wolf Mountain (Fig. 5) appears to be structurally inverted, while the sedimentary package immediately to its east is upright. This, together with the absence of hinge zone structures in the area and the widespread parallelism of bedding and cleavage, suggests the D1 folding was isoclinal. Major slicing probably took place along the fold hinges. Also the presence of isoclinally folded veins that crosscut the finely preserved bedding, indicates that considerable transposition occurred parallel to bedding. D1 vergence indicators suggest that most of the sedimentary rocks antiform toward the northwest. This would indicate that the intimately associated volcanic, volcaniclastic (unit V) and argillite (unit A) rocks represent the oldest portion of the supracrustal assemblage (Table 1).

A few minor D2 folds were seen in the area; these produce open to tight structures that deform the bedding and the D1 cleavage. This structural event is also believed responsible for many of the large scale orientation changes of the bedding-cleavage and for the arcuate swing in the trend of the mafic volcanic unit west and northwest of Tillicum Mountain (Fig. 5).

Several fault sets are identified. A major set of normal north to northeasterly trending faults partly controlled emplacement of the lamprophyre dyke swarms. Following intrusion of these dykes, this fault set was reactivated to produce fault breccias containing angular clasts of lamprophyre and country rock set in a matrix of white, vuggy, crystalline quartz. Some movement along this northerly trending fault system is post-Eocene in age, because faults of this set cut the Nemo Lakes stock (Parish, 1981).

A less important, southeast to south-southeasterly trending fault set occurs west of the Silver Queen mine, while west of Arnies Flats (Fig. 5) an east-northeast-striking zone of intense faulting is seen. This follows, in part, the margin of the Goatcanyon-Halifax Creeks stock and appears to control the Silver Jack mineralization.

TABLE 1

HISTORY OF EVENTS IN THE TILLICUM MOUNTAIN AREA

(8) Reactivation of northerly trending faults.

(7) Intrusion of lamprophyre dykes along pre-existing, north-south to northeast-trending faults.

(6) Intrusion of aplite sills and dykes.

(5) Intrusion of the Goatcanyon-Halifax Creeks stock with widespread hornfelsing along margins. Possible remobilization of some gold-silver mineralization as seen at the Silver Jack zone.

(4) D2 regional open to tight folding of schistose supracrustal rocks.

(3) D1 regional tight to isoclinal folding together with regional upper greenschist to amphibolite facies metamorphism. This was accompanied by the intrusion of the feldspar porphyry sills. Local hornfelsing, skarn formation, and introduction of gold-silver mineralization at the Heino-Money and Silver Queen mine zones.

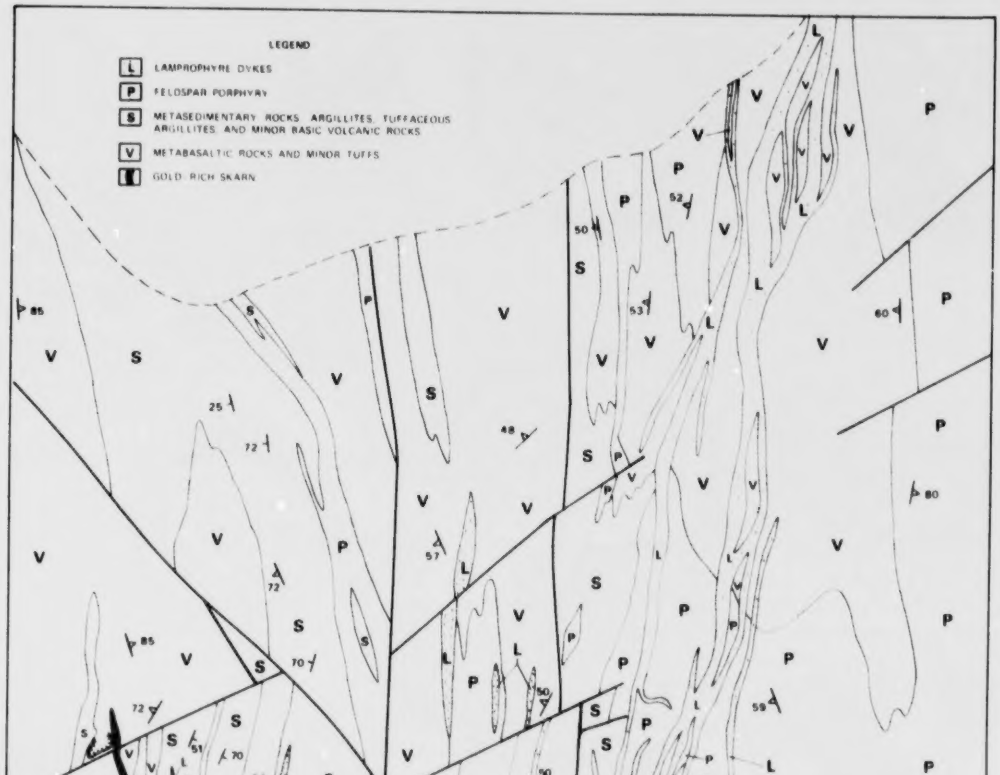
(2) Deposition of the mainly sedimentary sequence of arkose, siltstone, turbiditic wacke, and marls with rare mafic volcanic flows.

(1) Basaltic volcanism and deposition of volcaniclastic rocks and argillites.

MINERALIZATION IN THE TILLICUM MOUNTAIN AREA

The gold-silver mineralization in the district can be broadly separated into two types, namely:

(1) Gold and/or silver mineralization within skarn alteration that has a spatial, and possibly genetic, relationship to some feldspar porphyry sills (unit P) in the area. This type, which is widespread throughout the district, is best represented by the Heino-Money zone and mineralization at the Silver Queen mine.


LEGEND
L LAMPROPHYRE DYKES
P FELDSPAR PORPHYRY
S METASEDIMENTARY ROCKS, ARGILLITES, TUFFACEOUS ARGILLITES, AND MINOR BASIC VOLCANIC ROCKS
V METABASALTIC ROCKS AND MINOR TUFFS
GOLD-RICH SKARN
HEINO-MONEY ZONE (Au-Ag)
TILLICUM MOUNTAIN
N
SYMBOLS
FAULT
DIP AND STRIKE OF BEDDING
DIP AND STRIKE OF CLEAVAGE SCHISTOSITY
LIMITS OF MAPPING
0 20 60
metres

GEOLOGY BY W. ROBERTS & J. McCLINTOCK

Figure 6. Geology of the Heino-Money zone.

(2) Silver-gold mineralization within a siliceous and potassium-rich shear zone that shows no skarn development and is apparently unrelated to the feldspar porphyry sills. The Silver Jack mineralization, which is still very poorly understood, is the only example of this type identified in the area.

These two types of mineralization are described as follows:

SKARN-RELATED MINERALIZATION

At numerous localities throughout the Tillicum Mountain area, the margins of some feldspar porphyry sills, and the immediately adjacent country rock, are overprinted with skarn alteration that often carries geochemically anomalous amounts of gold and/or silver. These skarns are divisible into gold-rich and silver-rich types as represented respectively by the Heino-Money and Silver Queen mine mineralization.

At the Heino-Money zone the gold-bearing, siliceous, calc-silicate skarn alteration is stratabound; it is mainly hosted in a thin, wedge-shaped package of andesitic tuff and tuffaceous sediment which is bounded to the west by metabasalts and to the east by a large altered feldspar porphyry body (Fig. 6). The skarn is characterized by a pinkish green colour, and is generally well layered with subparallel, thin, quartz veins and variable amounts of sulphides. The skarn assemblage includes quartz, tremolite-actinolite, clinozoisite, plagioclase, diopside, biotite, garnet, and microcline with minor amounts of sericite and carbonate. Free gold occurs as fine to coarse disseminations and fracture fillings within and along the walls of quartz and sulphide impregnations; it is often associated with pyrrhotite, pyrite, galena, and sphalerite (Roberts and McClintock, 1984).

A polished section study of the Heino-Money mineralization (Northcote, 1983) indicated that individual gold grains range from less than 0.0025 millimetre to over several millimetres in diameter. The gold occurs as plates and anhedral grains which are generally free, but are also intimately associated with pyrrhotite, arsenopyrite, sphalerite, and pyrite-marcasite. Some pyrrhotite grains are rimmed with colloform pyrite-marcasite, while others contain small masses of hematite and graphitic material. Northcote (1983) also reports minor to trace amounts of tetrahedrite, chalcopyrite, and possible electrum.

The Silver Queen mine property was active in the 1930's, but reportedly work terminated after a spring avalanche closed the adit and caused the death of some miners. Intrusion of feldspar porphyry sills into a 30-metre-wide zone of impure calcareous metasedimentary rocks and thin marble beds was accompanied by stratabound skarn development. Two mineralized horizons up to 10 metres thick are recognized; mineralization and skarn alteration is found in both the altered marbles and the adjacent feldspar porphyry sills. However, mineralization differs from the Heino-Money zone in that it is silver dominant and gold is generally absent. The skarn assemblage includes quartz, tremolite-actinolite, clinozoisite, garnet, biotite, and carbonate with minor amounts of epidote and sphene. Anhedral garnet crystals up to 1 millimetre in diameter have clear margins but abundant inclusions in their cores. In some instances the garnet cores have overgrown and clearly preserved a biotite schistosity. Mineralization is traceable for 300 metres along strike and grades from 3 to 240 grams silver per tonne; gold is generally not detectable. Sulphides identified include pyrite, pyrrhotite, tetrahedrite, sphalerite, galena, and pyrargyrite.

SHEAR-RELATED MINERALIZATION

The only known example of shear-related mineralization is the Silver Jack zone on Arnies Flats, approximately 1.5 kilometres southwest of Tillicum Mountain (Fig. 5). The area is poorly exposed; the showing was discovered during follow-up work on a spectacular silver geochemical soil anomaly. Mineralization, which includes fine pyrite, sphalerite, rare chalcopyrite, and traces of molybdenite, extends for more than 300 metres along strike and averages 6 metres in width. It appears to occupy and follow a prominent east-southeast-trending shear zone that is quartz and potassium feldspar rich. This shear follows, in part, the margin of the Goatcanyon-Halifax Creeks stock and also cuts arkoses and siltstones in the sedimentary sequence. The zone averages 170 grams silver per tonne and 0.7 gram gold per tonne (McClintock and Roberts, 1984).

CONCLUSIONS

The Tillicum Mountain area contains a highly deformed supracrustal assemblage which is tentatively divisible into an older mafic volcanic-volcaniclastic sequence and a younger sedimentary sequence; there is no evidence that these are separated by either a structural break or unconformity. On lithological grounds the sedimentary rocks are correlated with the Slocan Group, while the older volcanic-argillite package are correlated with either the Slocan or Kalso Groups (Fig. 5).

The regional structural deformation involved an early D1 period of large scale, isoclinal folding with considerable shearing and attenuation along the hinge zones. Two hornfelsing episodes are recognized; the earliest is related to the intrusion of the feldspar porphyry sills (unit P), while the second was more widespread, postdates the regional deformation, and is associated with emplacement of the Goatcanyon-Halifax Creeks stock.

Most of the gold and/or silver mineralization in the district is associated with skarn development which is spatially, and possibly genetically, related to the intrusion of the feldspar porphyry sills. Garnets in the skarn alteration at the Silver Queen mine overgrow a pre-existing biotite schistosity; this suggests that the foliated, deformed feldspar porphyry sills were intruded sometime during the D1 regional folding. Thus the skarn-related mineralization, like the D1 structural event, is probably post-Early and pre-Late Jurassic in age.

The skarns are divisible into gold-rich and silver-rich types, as seen respectively at the Heino-Money and Silver Queen mine zones. It is uncertain whether these two types are synchronous and reflect a district scale gold-silver zoning, or whether they indicate two or more generations of mineralization. A third type of gold-silver mineralization is present at the Silver Jack zone. This is not related to skarns but is hosted in a silicified shear zone; the age and source of the Silver Jack mineralization are unknown.

ACKNOWLEDGMENTS

The authors wish to thank J. S. Brock of Esperanza Explorations Ltd. for permission to publish this data. Useful discussions with R. R. Parish of the Geological Survey of Canada are acknowledged, and thanks are expressed to M. Fournier for his competent and cheerful assistance in the field.

REFERENCES

Cairnes, C. E. (1934): Slocan Mining Camp, British Columbia, *Geol. Surv., Canada*, Mem. 173.

Hyndman, D. W. (1968): Petrology and Structure of Nakusp Map-area, British Columbia, *Geol. Surv., Canada*, Bull. 161, 95 pp.

Kwong, Y.T.J. and Addie, G. G. (1982): Tillicum Mountain Gold Prospect, *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1981, Paper 1982-1, pp. 38-45.

Little, H. W. (1960): Nelson Map-area, West Half, British Columbia, *Geol. Surv., Canada*, Mem. 308.

McClintock, J. and Roberts, W. (1984): Tillicum Gold-silver Property, *C.I.M.*, Ninth District 6 Meeting, Paper 7-1, Kamloops, Oct. 24-27, 1984.

Northcote, K. E. (1983): Petrography and Mineralography of the Tillicum Mountain Gold Porperty, *Vancouver Petrographics Ltd.*, unpub. rept., Jan. 1983, pp. 19.

Parrish, R. R. (1981): Geology of the Nemo Lakes Belt, Northern Valhalla Range, Southeast British Columbia, *Cdn. Jour. Earth Sci.*, Vol. 18, pp. 944-958.

Read, P. B. and Wheeler, J. O. (1976): Lardeau West-half, *Geol. Surv., Canada*, Open File Map 432.

Roberts, W. and McClintock, J. (1984): The Tillicum Gold Property, *Western Miner*, Vol. 57, No. 4, pp. 29-31.

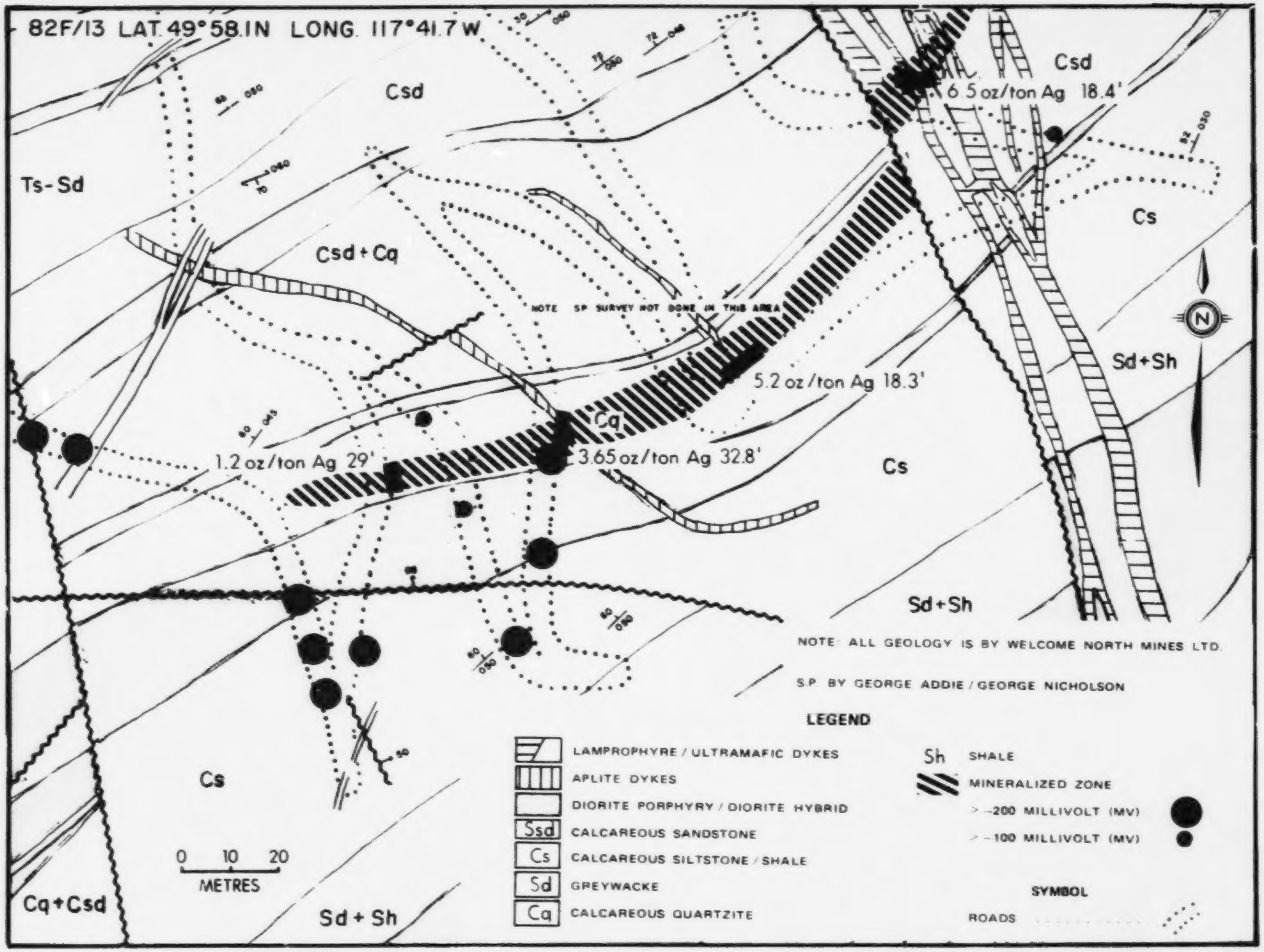

82F/13 LAT. 49°58.1N LONG. 117°41.7W
Csd
Ts-Sd
Csd + Cq
Cq
Cs
Sd+Sh
Cq+Csd
Sd + Sh
NOTE SP SURVEY NOT DONE IN THIS AREA
6.5 oz/ton Ag 18.4'
5.2 oz/ton Ag 18.3'
3.65 oz/ton Ag 32.8'
1.2 oz/ton Ag 29'
N
0 10 20
METRES
NOTE: ALL GEOLOGY IS BY WELCOME NORTH MINES LTD.
S.P. BY GEORGE ADDIE / GEORGE NICHOLSON
LEGEND
LAMPROPHYRE / ULTRAMAFIC DYKES
APLITE DYKES
DIORITE PORPHYRY / DIORITE HYBRID
Ssd CALCAREOUS SANDSTONE
Cs CALCAREOUS SILTSTONE / SHALE
Sd GREYWACKE
Cq CALCAREOUS QUARTZITE
Sh SHALE
MINERALIZED ZONE
> -200 MILLIVOLT (MV)
> -100 MILLIVOLT (MV)
SYMBOL
ROADS

Figure 7. Esperanza-Silver Queen self-potential test survey.

SELF-POTENTIAL TESTS AT THE SILVER QUEEN PROSPECT NEAR TILLICUM MOUNTAIN AND THE HAILSTORM MOUNTAIN GOLD PROSPECT

(82F)

By G. G. Addie

INTRODUCTION

Tillicum Mountain is 13 kilometres east of Burton and has a good truck road acess via Caribou Creek. The Silver Queen zone occurs on Grey Wolf Mountain which is a further 2 kilometres southeast from Tillicum Mountain. While the Caribou Nos. 3 and 4 claims are only 3 kilometres east of Tillicum Mountain (or 1.5 kilometres northeast of the Silver Queen zone), access is via a logging road along Shannon Creek which starts 3 kilometres south of Hills. The road ends at the headwaters of Caribou Creek. A new cat road continues 1 kilometre to the workings.

The Silver Queen zone is part of the Tillicum Mountain project operated by Esperanza Explorations Ltd., a company that holds an option to acquire 100 per cent ownership of this 6 000-hectare property.

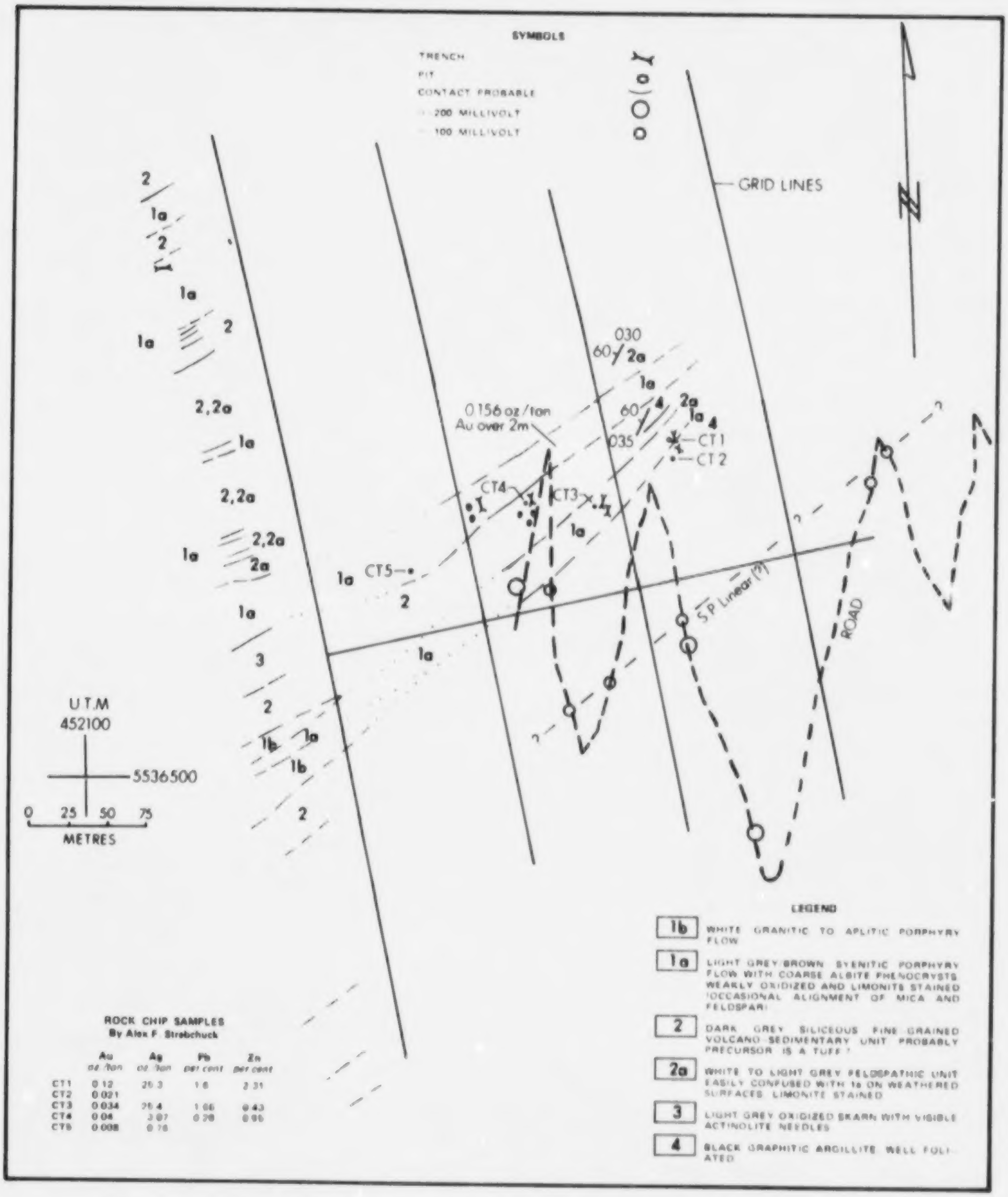
The Caribou Nos. 3 and 4 claims are wholly owned by Alex Strebchuck of Hills.

GENERAL GEOLOGY

All the geological information at the Silver Queen zone has been provided by Mr. J. McClintock of Welcome North Mines Ltd., and on the Caribou claims by Mr. T. R. Stokes.

Both areas are underlain by the Milford Group (Pennsylvanian to Triassic ?; Hyndman, 1968) sedimentary rocks which include a diorite porphyry. Both have been subjected to regional metamorphism believed to predate the Cretaceous Goatcanyon-Halifax Creeks stocks. At the Caribou claims this porphyry is described as 'light grey-brown syenite porphyry.' These units have been intruded by the plutonic rocks followed by small aplite-alaskite dykes, ultramafic dykes, and lamprophyre dykes. Younger faults (of unknown age) are mapped in the Silver Queen area, but have not been mapped at the Caribou prospect to date.

The gold and silver mineralization is believed to be associated with the 'sill-like' porphyries because of their spatial relationships, and in some cases because of the development of skarn minerals. While the Caribou claim geology is approximately on strike with the Silver Queen zone, it should be pointed out that Assessment Report 11141 (Smith, 1983) indicates a considerable zone of silver mineralization (61 metres) approximately 500 metres north of the Caribou claims.


SYMBOLS
TRENCH
PIT
CONTACT PROBABLE
200 MILLIVOLT
100 MILLIVOLT
GRID LINES
030
60
2a
1a
0.156 oz/ton
Au over 2m
60
4
2a
1a
4
035
CT1
CT2
CT4
CT3
CT5
S.P. Linear (?)
ROAD
U.T.M
452100
5536500
0
25
50
75
METRES
2
1a
2
1a
2
1a
2,2a
1a
2,2a
2,2a
1a
2a
1a
2
1a
3
1a
2
1b
1a
1b
2

ROCK CHIP SAMPLES
By Alex F. Strebchuck

	Au oz./ton	Ag oz./ton	Pb per cent	Zn per cent
CT1	0.12	25.3	1.6	2.31
CT2	0.021			
CT3	0.034	25.4	1.66	0.43
CT4	0.04	3.07	0.20	0.95
CT5	0.008	0.76		

LEGEND

1b	WHITE GRANITIC TO APLITIC PORPHYRY FLOW
1a	LIGHT GREY-BROWN SYENITIC PORPHYRY FLOW WITH COARSE ALBITE PHENOCRYSTS WEAKLY OXIDIZED AND LIMONITE STAINED (OCCASIONAL ALIGNMENT OF MICA AND FELDSPAR)
2	DARK GREY SILICEOUS FINE GRAINED VOLCANO SEDIMENTARY UNIT PROBABLY PRECURSOR IS A TUFF ?
2a	WHITE TO LIGHT GREY FELDSPATHIC UNIT EASILY CONFUSED WITH 1a ON WEATHERED SURFACES LIMONITE STAINED
3	LIGHT GREY OXIDIZED SKARN WITH VISIBLE ACTINOLITE NEEDLES
4	BLACK GRAPHITIC ARGILLITE WELL FOLIATED

Figure 8. Self-potential road traverse of Caribou Nos. 3 and 4 claims. Geology after T. R. Stokes.

SELF-POTENTIAL (S.P.) TESTS

Past work at Tillicum Mountain has indicated long, continuous self-potential (S.P.) anomalies, some of which have been associated with mineral zones (for example, the Money pit and the Jennie zone). The following S.P. tests were conducted to further understanding of the causes of these anomalies, and at the same time to train new prospectors in this technique of exploration.

SILVER QUEEN SILVER ZONE

A 'long wire' (200 metres) prospecting method was used on the road crossing the Silver Queen mineral zone (Fig. 7). Although the survey was not closed, strong anomalies were identified in the footwall area, described as 'calcareous siltstone/shale.' This unit was also observed to contain graphite, which is probably the cause of some of the anomalies. On the other hand, one S.P. anomaly was right over the mineral zone, which assays 3.65 ounces silver per ton and is in a calcareous quartzite unit. Other S.P. anomalies in 'calcareous sandstone and calcareous quartzite' remain to be explained.

HAILSTORM MOUNTAIN

At this property (Fig. 8) gold particles have been obtained by panning the soil. A cat road has been made to reach these locations, and float from the last switchback assayed 1 ounce gold per ton. A bedrock sample at the same location, across 2 metres, was taken by Mr. J. McClintock for Esperanza; it assayed 0.156 ounce gold per ton. While doing an S.P. test on the cat road, a graphite shear zone containing calcite and galena and bearing north 40 degrees east-32 degrees west was noted. Some of the sediments also contain graphite.

A 'short wire' method was used in the S.P. test. Three strong anomalies of less than -200 millivolt were located, but the most interesting values are in the -100 to -200 millivolt range; these indicate a linear anomaly; the cause is not known.

RECOMMENDATIONS

SILVER QUEEN ZONE

The calcareous siltstone/shale unit (Cs) in the footwall area of the mineral zone apparently contains graphite. Outcrops in areas with S.P. anomalies should be assayed to determine if any precious metals are present. If so, further S.P. surveys should be carried out.

CARIBOU CLAIMS

Geological mapping along the cat road is required to explain the S.P. anomalies located by this survey. If bedrock is present at these locations, it should be assayed for gold and silver.

CONCLUSION

Self-potential tests at the Silver Queen and Hailstorm Mountain prospects were successful in obtaining S.P. anomalies, most of which are thought to be due to the presence of graphite. All should be checked by assaying available outcrops for precious metals. If the results are positive, further S.P. surveys would be warranted.

ACKNOWLEDGMENTS

Information about the Silver Queen geology and assay results was provided by Mr. J. McClintock of Welcome North Mines Ltd.; permission to use the Caribou Nos. 3 and 4 claims geology was given by Mr. T. R. Stokes. The S.P. equipment, except for the spool, came from Mr. J. M. Thornton of North Vancouver; the self-potential spool of wire was donated by Mr. Greg Filion of Cranbrook.

REFERENCES

Hyndman, D. W. (1968): Petrology and Structure of Nakusp Map-area, British Columbia, *Geol. Surv., Canada*, Bull. 16.

Smith, F. M. (1983): Geological Report for Assessment Credits, London 1 and London 2 Mineral Claims, *B.C. Ministry of Energy, Mines & Pet. Res.*, Assessment Report 11141.

STRUCTURAL MODELLING OF PARTS OF THE NORTHERN DOMINION COAL BLOCK (PARCEL 73), SOUTHEASTERN BRITISH COLUMBIA

(82G/10)

By D. A. Grieve and W. E. Kilby

INTRODUCTION

The Dominion Coal Block consists of two parcels of land owned by the Federal Government in the Crowsnest Coalfield, or Fernie Basin, of southeastern British Columbia. Although these 20 235 hectares were not conveyed to the Federal Government until 1905, their acquisition was guaranteed in the Crows Nest Pass Act of 1897 (Ollerenshaw, 1981). Thus their creation was intimately related to the original development of the Crowsnest Pass area and its abundant coal deposits.

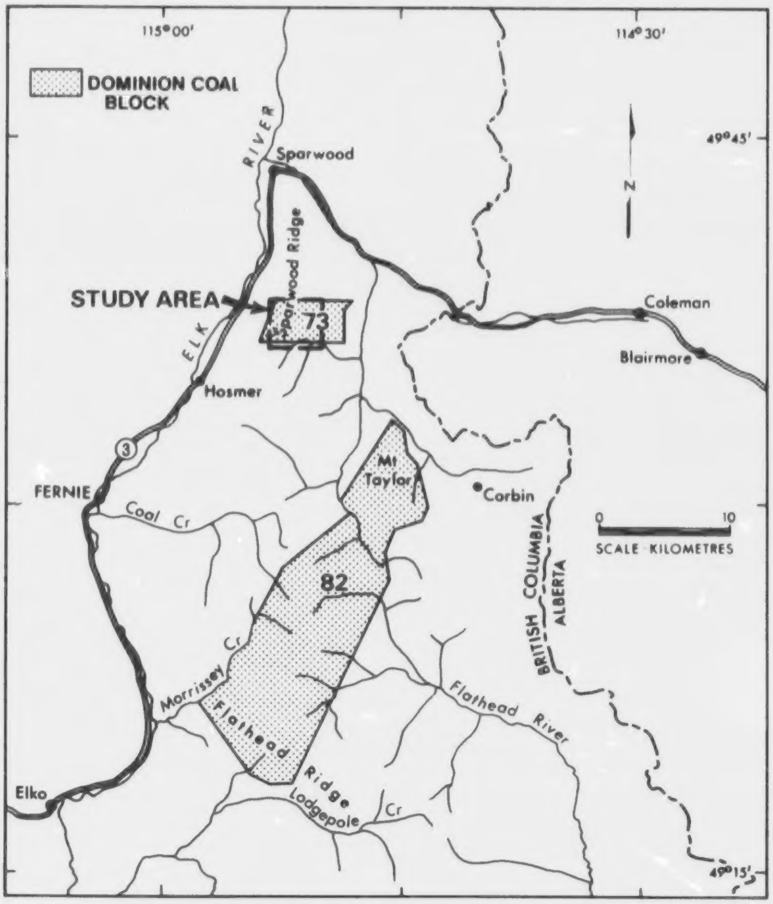

115°00'
114°30'
DOMINION COAL BLOCK
49°45'
N
ELK RIVER
Sparwood
Sparwood Ridge
STUDY AREA
73
Coleman
Blairmore
Hosmer
3
Mt Taylor
Corbin
FERNIE
Coal Cr
0
10
SCALE KILOMETRES
82
BRITISH COLUMBIA
ALBERTA
Morrissey Cr
Flathead River
Flathead Ridge
Elko
Lodgepole Cr
49°15'

Figure 9. The Crowsnest Coalfield area, showing the locations of Parcels 73 and 82 of the Dominion Coal Block.

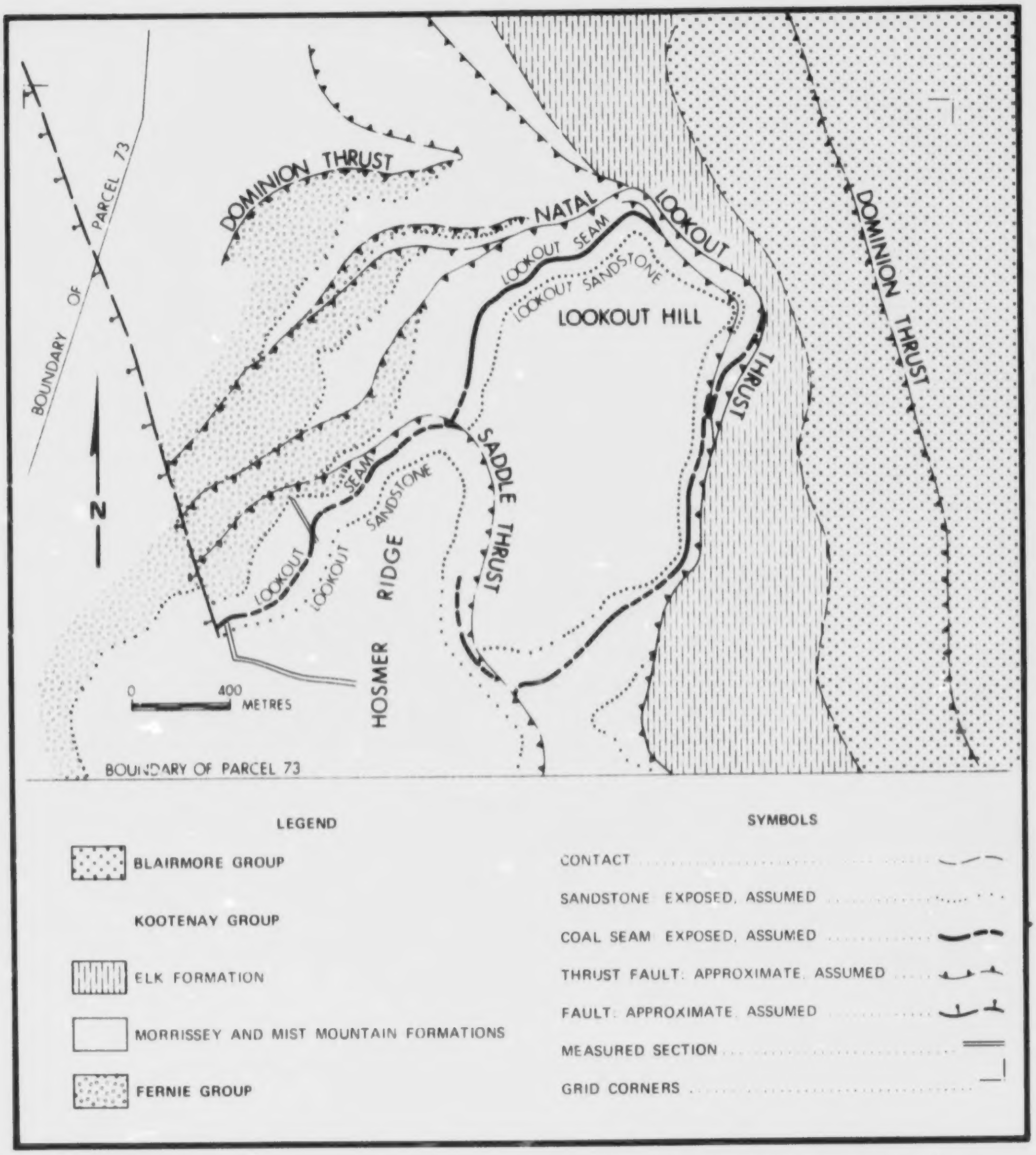

DOMINION THRUST
BOUNDARY OF PARCEL 73
NATAL
LOOKOUT
LOOKOUT SEAM
LOOKOUT SANDSTONE
LOOKOUT HILL
THRUST
DOMINION THRUST
SADDLE THRUST
SEAM
SANDSTONE
LOOKOUT
LOOKOUT
RIDGE
HOSMER
N
0
400
METRES
BOUNDARY OF PARCEL 73
LEGEND
BLAIRMORE GROUP
KOOTENAY GROUP
ELK FORMATION
MORRISSEY AND MIST MOUNTAIN FORMATIONS
FERNIE GROUP
SYMBOLS
CONTACT
SANDSTONE: EXPOSED, ASSUMED
COAL SEAM: EXPOSED, ASSUMED
THRUST FAULT: APPROXIMATE, ASSUMED
FAULT: APPROXIMATE, ASSUMED
MEASURED SECTION
GRID CORNERS

Figure 10. Generalized geology of the southwest portion of Parcel 73 (modified after Ollerenshaw, et al., 1977).

Restrictions on development of coal resources within the block were contained in the Act. For example, any coal produced was to be sold for not more than $2.00 per short ton. The recent passing of the *Western Grain Transportation Act* (Bill C-155) removed this anachronistic condition, and thus removed a major obstacle to development of the block.

Parcel 73 is the more northerly of the two parcels (Fig. 9), and at 2 023.5 hectares is also the smaller. It lies at the south end of Sparwood Ridge and north end of Hosmer Ridge, 10 kilometres south of Sparwood. Elevations range from 1 380 to 2 280 metres; local relief is as extreme as anywhere in the Crowsnest Coalfield. It is surrounded by Freehold coal lands held by Westar Mining Ltd.

Provincial coal licences on Parcel 73 were held at one time by Kaiser Resources Ltd. (now Westar Mining); later these were revoked. Kaiser Resources carried out exploration between 1969 and 1971, including geological surveys, eight rotary drill holes, twelve adits, and two test pits.

A geological investigation involving both the British Columbia Ministry of Energy, Mines and Petroleum Resources and the Geological Survey of Canada was carried out in 1975 and 1976 (Ollerenshaw, 1977; Ollerenshaw, *et al.*, 1977). One product of this work was a 1:10 000-scale geological map plotted on an orthophoto base (Ollerenshaw, *et al.*, 1977). This map was used as the basis for computer modelling of portions of Parcel 73 as described in this report. A minor amount of fieldwork was carried out in 1984 to supplement results of the earlier investigation.

This study focuses on the portion of Parcel 73 which appears to have potential as an open-pit mine. This area is located on Lookout Hill, named for an abandoned Forestry lookout tower (Fig. 10).

STRATIGRAPHY

Economic coal seams of southeastern British Columbia are contained in the non-marine Mist Mountain Formation of the Jurassic-Cretaceous Kootenay Group. The Mist Mount Formation conformably overlies Morrissey Formation sandstone, and is overlain by clastic sedimentary rocks and thin coal seams of the Elk Formation.

Parcel 73 is underlain not only by all three formations of the Kootenay Group, but also by the underlying Fernie Group and overlying Blairmore Group (Fig. 10).

Approximately 490 metres of the Mist Mountain Formation are preserved on Hosmer Ridge (Fig. 10); the uppermost 100 metres were eroded. The thickness of Mist Mountain Formation rocks on Lookout Hill is less than 200 metres.

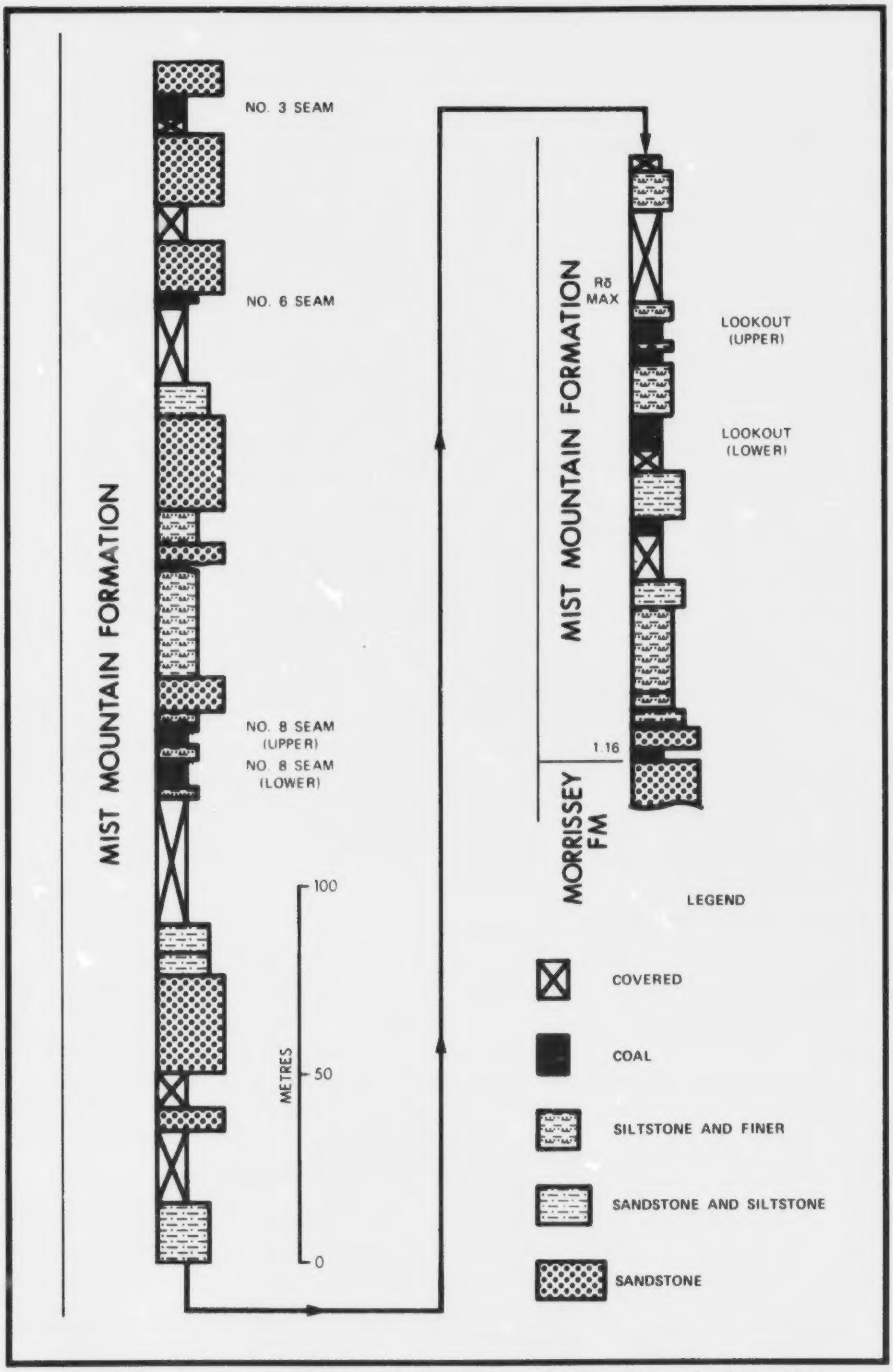

MIST MOUNTAIN FORMATION
NO. 3 SEAM
NO. 6 SEAM
NO. 8 SEAM (UPPER)
NO. 8 SEAM (LOWER)
METRES
100
50
0
MIST MOUNTAIN FORMATION
Rō MAX
LOOKOUT (UPPER)
LOOKOUT (LOWER)
1.16
MORRISSEY FM
LEGEND
COVERED
COAL
SILTSTONE AND FINER
SANDSTONE AND SILTSTONE
SANDSTONE

Figure 11. Measured stratigraphic section of Mist Mountain Formation on Hosmer Ridge (see Fig. 10 for location).

The section exposed on Hosmer Ridge contains in excess of 45 metres of coal in six zones. The most prominent coal zone, dubbed the 'Lookout seam' by Ollerenshaw (1977), lies near the base of the section. It constitutes the bulk of potentially economic coal resources throughout the study area, particularly on Lookout Hill (Fig. 10). At the position of the measured section it consists of 19 metres of coal in three distinct benches that are separated by interbedded coal and shale (Fig. 11); all occur within 35 metres of section.

A prominent sandstone, which overlies the Lookout seam by an average of 10 metres, was named the 'Lookout sandstone' by Ollerenshaw (1977). It forms a dip-slope cap on Lookout Hill, where it has protected the Lookout seam from erosion.

STRUCTURE

The study area lies on the western limb of the Fernie Basin, a complex synclinorium. This portion of the basin is affected by a series of imbricate, southwest-dipping thrust faults and splays (Fig. 10). The major faults are named, from top to bottom, the Saddle, Natal Lookout, and Dominion thrusts.

From an economic point of view the Natal Lookout thrust is the most significant. Its trace divides Parcel 73 into two distinct areas, and, in the hangingwall, coal seams of the Mist Mountain Formation lie in close proximity to the surface on Lookout Hill and Hosmer Ridge (Fig. 12).

Movement on the Saddle thrust was documented by Ollerenshaw, *et al.*, (1977); its displacement is minor and it has not been included in any of the analysis that follow. Coal seams line up very well across the Saddle thrust (Fig. 12). The structure of the strata above the Natal Lookout thrust is best described as monoclinal and with mean orientation of 182/13.5 (DIP-DIRECTION/DIP). Data from the whole area suggests a regional fold axis orientation of 165/12 (TREND/Plunge). Examination of the map data (Ollerenshaw, *et al.*, 1977) shows that the Natal Lookout and Saddle thrust have similar orientation, about 216/17 (DIP-DIRECTION/DIP).

COAL RANK DISTRIBUTION

Coal rank, expressed as $\bar{R}_o$ max or maximum vitrinite reflectance in oil, was determined on 15 samples. Values for samples corresponding to the basal part of the measured section are shown on Figure 11. They range from 1.16 per cent for the seam immediately overlying the Morrissey Formation, to 1.06 per cent for the upper bench of the Lookout seam. Seams higher in the section on Hosmer Ridge have reflectance values ranging from 1.04 to 0.99 per cent (not shown on section since sample sites did not correspond with the section location).

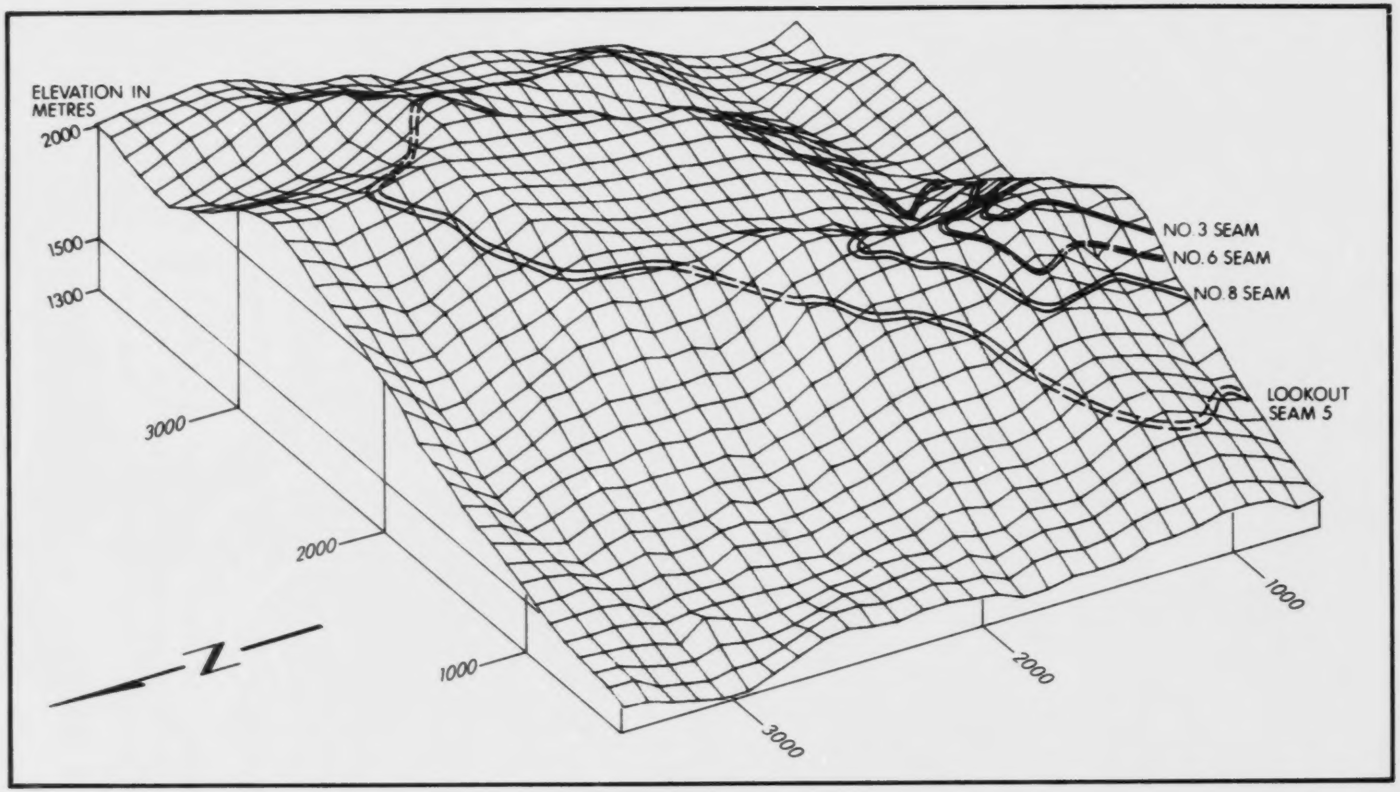

ELEVATION IN METRES
2000
1500
1300
3000
2000
1000
1000
2000
3000
N
NO. 3 SEAM
NO. 6 SEAM
NO. 8 SEAM
LOOKOUT SEAM 5

Figure 12. Isometric diagram of the surface topography of the study area with coal seams displayed. Each net square is 100 metres on a side. The view is that seen by looking down on the deposit in a southeasterly direction.

The division between ASTM rank categories high-volatile bituminous and medium-volatile bituminous is in the vicinity of 1.1 per cent $\bar{R}_o$max. Thus the Lookout seam at the location of the measured section falls near the boundary between high and medium-volatile rank as determined petrographically; the upper seams on Hosmer Ridge are all of high-volatile rank. Actual volatile matter contents of the Lookout seam may be somewhat lower than expected from these results, because seams from the lower part of the Mist Mountain Formation have relatively high inertinite content (Cameron, 1972).

Within the study area the rank of the Lookout seam appears to decrease toward the northeast and increase toward the southwest. For example, reflectance of a sample of the Lookout seam from the north spur of Lookout Hill is 0.91 per cent, while the basal seam in the Mist Mountain Formation at a point 650 metres south of the southwest corner of Parcel 73 has a reflectance of 1.26 per cent. In the latter case the Lookout seam might reasonably be expected to have a reflectance in the neighbourhood of 1.2 per cent. The difference in elevation between these two points is approximately 770 metres, suggesting that the contrast is at least partly due to down-dip rank increases, as was noted to be the case at several other locations in the Crowsnest Coalfield (Pearson and Grieve, in press). This change in rank with elevation (0.038 per cent/100 metres) is, in fact, only slightly higher than that established at Coal Creek, 15 kilometres to the south, for purely down-dip rank increase (0.035 per cent/100 metres).

The relatively low rank of coals above the Dominion thrust fault compared with those of adjacent areas was noted by Pearson and Grieve (in press). The Balmer seam, which lies at approximately the same stratigraphic position as the Lookout seam on Sparwood Ridge, has reflectance values of approximately 1.4 per cent. The lower rank of coals within the study area makes them attractive under present market conditions.

DEPOSIT MODEL

Calculation of coal resources contained in the Northern Dominion Coal Block was one of the main objectives of this study. To this end a computer deposit model was constructed. Given the appropriate software, computer deposit models are easier to construct and evaluate than those made by traditional manual deposit analysis techniques involving multiple plans and sections. A computer deposit model also has the advantage of being readily available to answer a wide variety of questions about the deposit. This deposit is areally small and, on the basis of the data available, geologically straightforward.

Equipment used for modelling consisted of a KAYPRO II portable micro-computer, an EPSON MX-80 printer, and a ROLAND DXY-800 plotter. All equipment is portable and relatively inexpensive; the total cost of all hardware is less than $4500. Software used was the GRID HANDLER module of the GEOLOGICAL ANALYSIS PACKAGE, designed by Cal Data Ltd., and on loan to the Ministry.

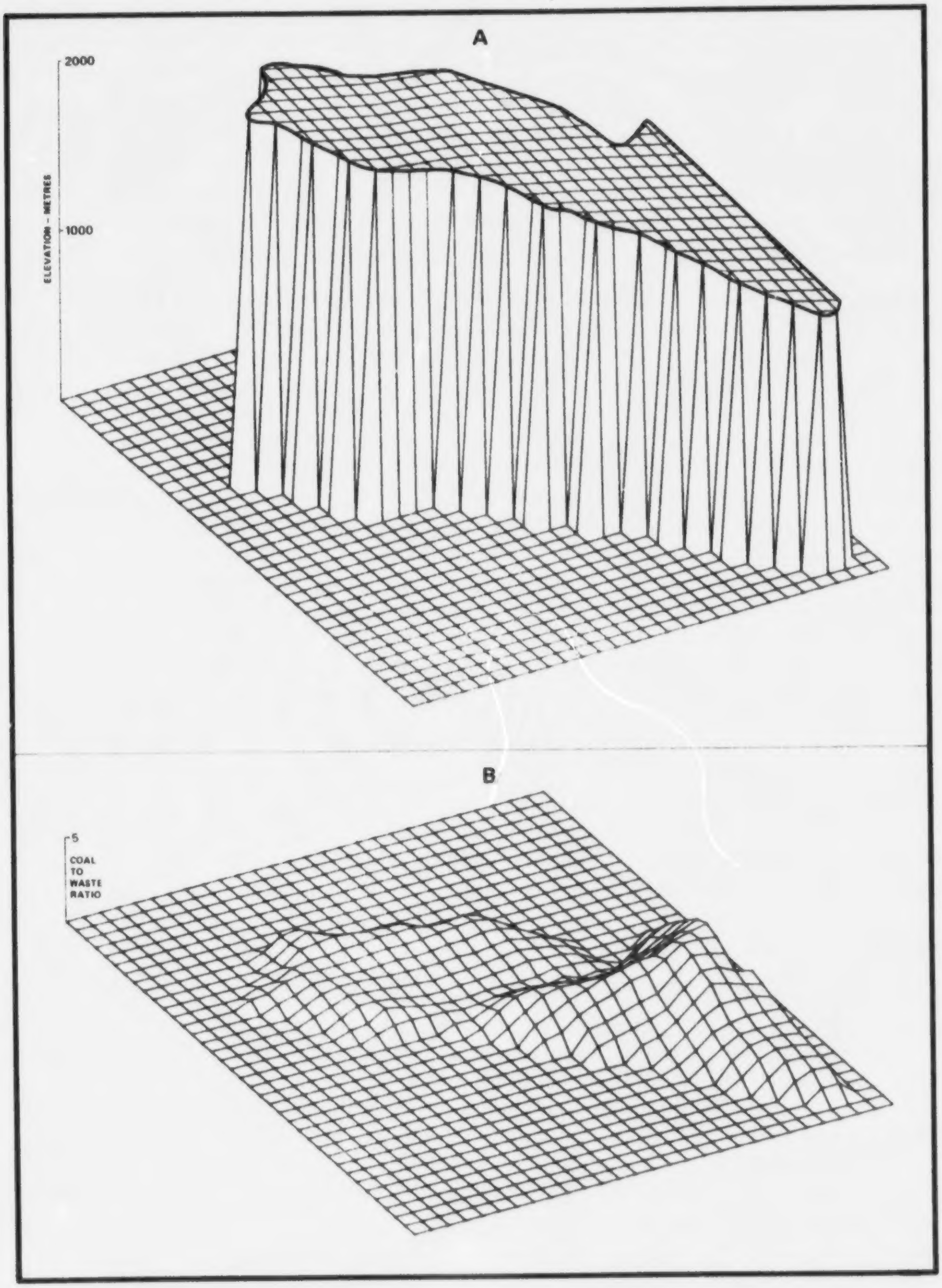

A
2000
ELEVATION - METRES
1000
B
5
COAL
TO
WASTE
RATIO

Figure 13. Isometric net diagrams related to the upper Lookout seam. (a) Display of the seams structure contour grid. The vertical drop-off marks the outcrop edge of the seam. (b) View of the amount of material above the seam.

The computer model produced consisted of a series of digital surfaces, each defining a specific parameter of the deposit, such as topography and seam position. Each digital surface is in the form of a grid that covers the study area; the value of the desired parameter is determined and stored for the centre position of each grid square. By numerically overlaying various grids, calculations such as overburden ratios and tonnages can be made.

The selected grid outline, which is shown on Figure 10, covers only the area of the coal block containing the Natal Lookout thrust sheet. The grid is 2.9 kilometres in an east-west direction and 3.7 kilometres in a north-south direction. A grid spacing of 100 by 100 metres was selected because it provided reasonable resolution of the deposit features. Available data did not warrant a finer grid and a larger grid spacing would have insufficient resolution to provide an accurate assessment of the resource potential of the property.

Digitial surfaces were calculated by a variety of methods. The topographic grid was obtained by hand digitizing an enlarged 1:50 000-scale topographic map with 100-foot contours. A network of points corresponding to the centres of the grid squares were superimposed on this map. The elevations from each point were manually interpolated from surrounding contour lines and the data entered and stored in the appropriate format in the computer.

Coal seam structure contour surfaces were obtained by a down-plunge projection technique similar to the method described in Gold, *et al.* (1981). The positions of seam outcrops and borehole intersections, if available, were projected parallel to strike lines or the fold-axis orientation onto the computer screen. The projection direction was interactively adjusted until the best projection direction was determined. This best projection direction was the orientation which superimposed widely spaced data from the same horizon in a form that was geologically acceptable to the examiner. Upon obtaining a satisfactory projection direction, all seam data are plotted onto a section oriented normal to the projection direction (*see* SECTION - A Micro-computer Program, this volume). The profile was then geologically interpreted; that is, the trace of each seam was drawn on the profile. The trace was then digitized by hand and the data input into a program which projected the trace parallel to the projection direction over the model area and calculated the elevation of the surface at each of the grid centres. In cases such as the Lookout and No. 8 seams, where two seams are stratigraphically very close together, the lower seam position was calculated by subtracting the stratigraphic interval between the two seams from the structure contour grid calculated for the upper seam in each pair. In this manner six seam surfaces were defined: No. 3, No. 6, No. 8 upper, No. 8 lower, Lookout upper, and Lookout lower.

Once the positions of the seams were established, the seam structure contour grids were then compared with the topographic grid. Where the

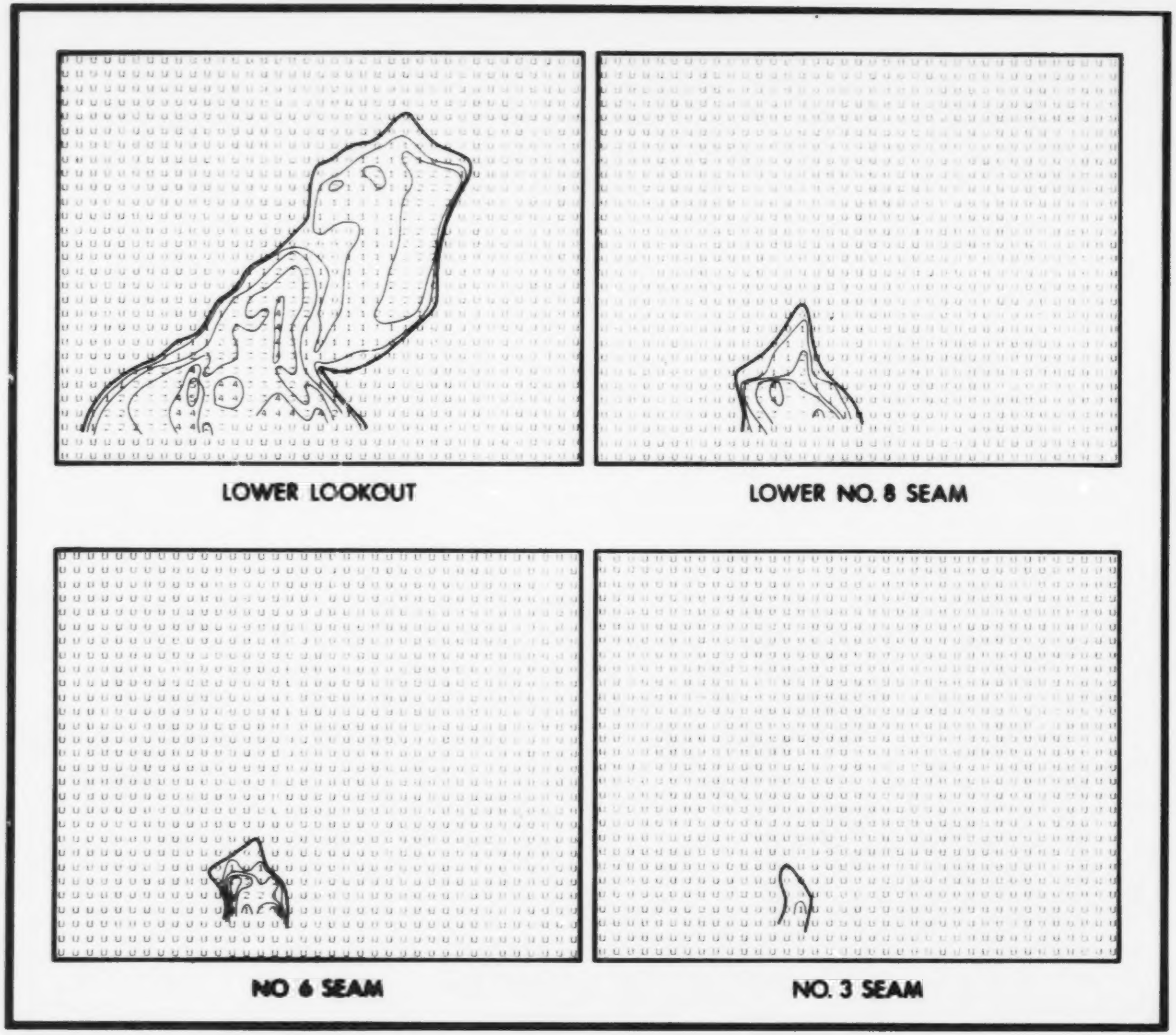

LOWER LOOKOUT
LOWER NO. 8 SEAM
NO 6 SEAM
NO. 3 SEAM

Figure 14. Map displays showing the distribution of the waste to coal ratio values cumulated to the base of four coal seams. u = undefined; 0 = 0 to 2 m; 1 = 2 to 4 m; 2 = 4 to 6 m; 3 = 6 to 8m; 4 = 8 to 10 m.

seam elevations were greater than the topographic elevations, the relevant grid positions were flagged, trimmed, so as not to be used in future calculations. As a check on the accuracy of the method, the seam outcrop trace obtained by this method was compared with the same trace observed on the geological map. In places discrepancies of up to 300 metres, three grid squares in map view, were present. Therefore the seam structure contour grid was modified so the model seam outcrop trace matched the observed trace. The most likely cause of these discrepancies was the poor topographic control. Figure 13a contains isometric displays of the upper Lookout seam structure contour grid after trimming at the outcrop. Each square is 100 metres on a side. Figure 13b is an isometric view of the difference between the topographic grid and the upper Lookout seam structure contour grid - an illustration of the cover on this seam.

Several interpretation assumptions were built into the model, usually due to a lack of data:

(1) The Saddle thrust was not incorporated in the model because at the resolution of the model its effect on the geology was insignificant.

(2) The Lookout seams were assumed continuous in the northeast and southwest portions of the model even though complications were apparent from the published geology map. In both cases faulting was indicated and the seams were not represented on the published map (Ollerenshaw, *et al.*, 1977), but in both areas the seam would be present but with some displacement due to the faulting. Thus the total coal calculation would appear similar in any case.

(3) All seams were considered to be of a uniform thickness, the thickness values used were those obtained from the measured section (Fig. 11).

(4) It was assumed that the coal seam positions could be described by a line moving parallel to the projection direction, 115/0, and joining all known outcrops of a seam. The projection direction did not correspond with the fold-axis orientation for the area, but with the data available the chosen direction proved to most accurately describe the known position of the seams. The coal seam positions will require modification when additional information from the interior of the deposit become available.

(5) The coal was assumed to be of a constant specific gravity in each seam and across the deposit. No information was available to allow assessment of this assumption.

(6) No dilution or recovery factors were assumed, all calculations were strictly on an in-place basis.

The model contains seven digital surfaces; the topographic grid, and the surface elevation grids of six coal seams. A seam thickness is known for each seam and a specific gravity value can be estimated. With this information nearly all resource assessment questions are answerable.

Table 1 contains a tabulation of the volumes and tonnages of coal determined for each of the six seams. Also noted on the left side of the table are the amounts that these totals would fluctuate if the seam thickness varied by 10 centimetres or if one grid square were included or excluded from the calculations. As seen from these calculations, a total resource of greater than 75 million tonnes is estimated to be in place; several small seams and seams whose positions are not well understood at present are excluded from these calculations. Table 2 contains a summary of waste rock to coal ratio for each seam, as well as the cumulative waste to coal ratios for the whole deposit starting with the uppermost seam and working downward. Thus if the whole deposit were to be mined to the level of the lower Lookout seam, the overall mining ratio would be 4.7:1 (BCM:tonne); 389 million cubic metres of waste rock would have to be moved. Figure 14 contains map displays of these mining ratios in a cumulative fashion from the upper to lower seam. It is obvious from these maps and Figure 13 that there is a considerable amount of low mining ratio coal in the north and east portions of the deposit.

TABLE 1
POTENTIAL COAL RESOURCES ON PARCEL 73

Seam	Area (sq. m) (x 10 000)	Thickness metres	S.G.	Tonnes	Range ± /10 cm	Range ± /grid sq.
No. 3	7	6.1	1.32	563 640	9 240	80 520
No. 6	19	1.5	1.32	285 000	25 080	19 800
No. 8 upper	41	4	1.32	2 164 800	54 120	52 800
No. 8 lower	41	7.3	1.32	3 950 760	54 120	96 360
Lookout (U)	277	9.754	1.32	35 664 525	365 640	128 752
Lookout (L)	277	9.14	1.32	33 419 496	365 640	120 648
				76 048 221		

TABLE 2
INDIVIDUAL AND CUMULATIVE WASTE-COAL RATIOS

Seam	Total Coal (Tonnes)	Total Waste (BCM)	Ratio	Cumulative Ratio
No. 3	563 640	760 502	1.35	1.35
No. 6	285 000	5 082 400	17.83	5.5
No. 8 upper	2 164 800	29 752 400	13.74	9.67
No. 8 lower	3 950 760	33 001 700	8.35	4.4
Lookout (U)	35 664 525	306 976 000	8.61	7.08
Lookout (L)	33 419 496	389 799 000	11.66	4.7

CONCLUSION

The Northern Dominion Coal Block, Parcel 73, contains significant coal resources. Greater than 75 million tonnes of *in situ* coal are extractable by open pit methods at a mining ratio of less than 5:1. Coal rank is medium to high-volatile bituminous with $\bar{R}_o$max values in the 1.16 to 0.91 per cent range. The deposit is ideally situated with respect to all required infrastructure.

REFERENCES

Cameron, A. R. (1972): Petrography of Kootenay Coals in the Upper Elk River and Crowsnest Areas, British Columbia and Alberta, *Res. Counc. Alberta,* Information Series No. 60, pp. 31-45.

Gold, C. M., Charlesworth, H.A.K., and Kilby, W. E. (1981): Coal Resource Evalution in Deformed Sequences Using Digital Terrain Models, *Cdn. Pet. Geol.,* Bull., Vol. 29, No. 2, pp. 259-266.

Ollerenshaw, N. C. (1977): Canadian Government Coal Block, Parcel 73, Fernie, *in* Current Research, Part A, *Geol. Surv., Paper 77-1A, pp. 155-159.*

.... *(1981): Parcel 82 Dominion Coal Block, Southeastern British Columbia, in* Current Research, Part B, *Geol. Surv., Canada,* Paper 81-1B, pp. 145-152.

Ollerenshaw, N. C., Pearson, D. E., Gigliotti, F., and Grieve, D. A. (1977): Geology of Crowsnest Coalfield, Northwest Part, *B.C. Ministry of Energy, Mines & Pet. Res.,* Preliminary Map 24, Sheet 3.

Pearson, D. E. and Grieve, D. A. (in press): Rank Distribution and Coalification Pattern, Crowsnest Coalfield, British Columbia, Canada, *C.I.M.,* Bull., Vol. 78.

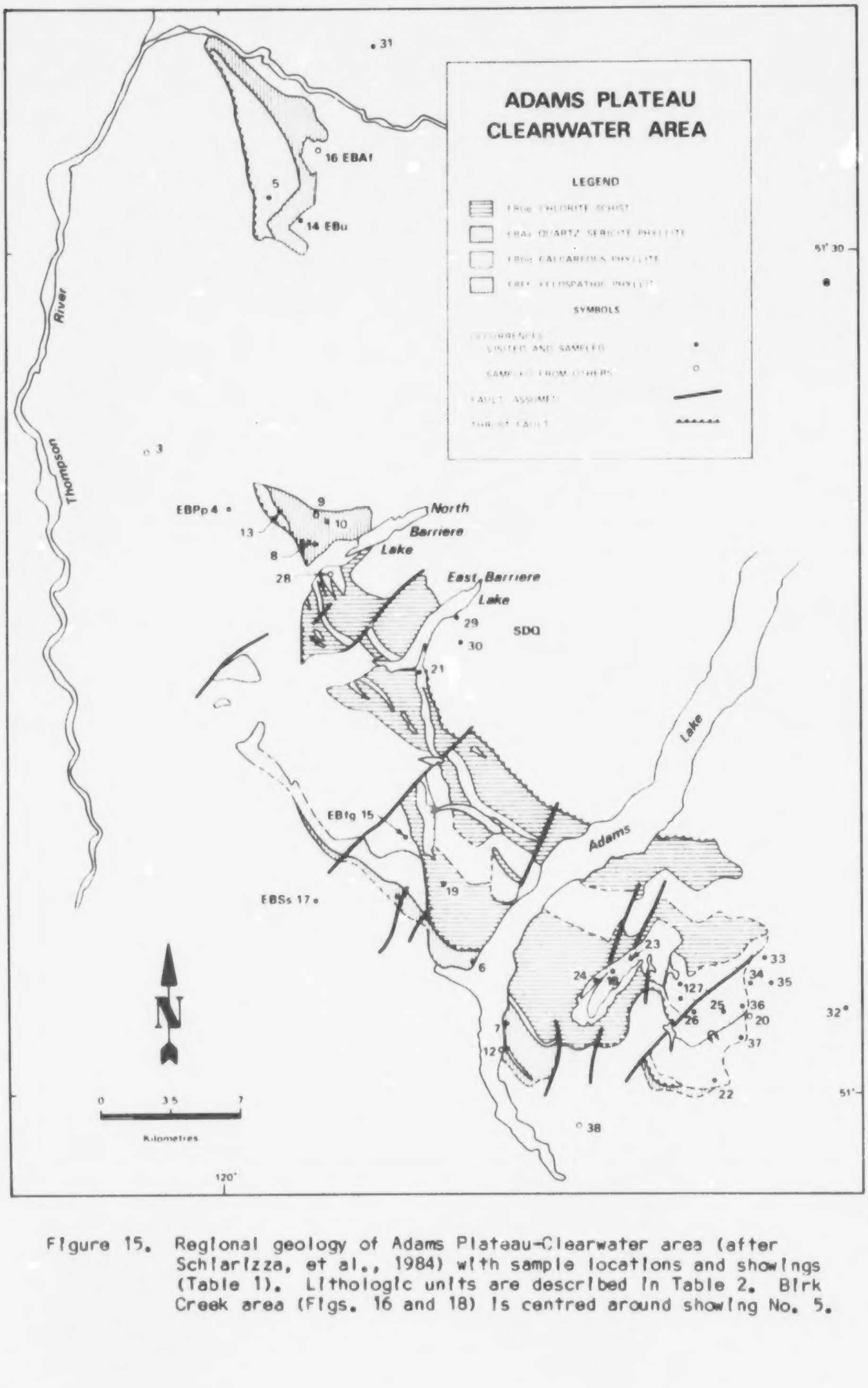

ADAMS PLATEAU
CLEARWATER AREA
LEGEND
EBgs CHLORITE SCHIST
EBAf QUARTZ SERICITE PHYLLITE
EBcp CALCAREOUS PHYLLITE
EBfp FELDSPATHIC PHYLLITE
SYMBOLS
OCCURRENCES
VISITED AND SAMPLED
SAMPLED FROM OTHERS
FAULT ASSUMED
THRUST FAULT
Thompson
River
North
Barriere
Lake
East Barriere
Lake
Adams
Lake
SDQ
31
16 EBAf
5
14 EBu
3
EBPp 4
9
6
10
13
8
28
29
30
21
EBfg 15
EBSs 17
19
6
23
24
127
33
34
35
25
26
36
20
37
7
12
22
38
51°30
32°
51°
120°
N
0
3.5
7
Kilometres

Figure 15. Regional geology of Adams Plateau-Clearwater area (after Schiarizza, et al., 1984) with sample locations and showings (Table 1). Lithologic units are described in Table 2. Birk Creek area (Figs. 16 and 18) is centred around showing No. 5.

MINERAL DEPOSITS IN THE BIRK CREEK AREA: AN INTRODUCTION TO A METALLOGENIC STUDY OF THE ADAMS PLATEAU-CLEARWATER AREA,
(82M)

By F. Goutier and C. I. Godwin
Department of Geological Sciences, University of British Columbia
and
T. Höy
Ministry of Energy, Mines and Petroleum Resources

INTRODUCTION

Mineral deposits in the Adams Lake-Clearwater area, centred 35 kilometres northeast of Kamloops, were studied during July and August, 1984 by the senior author. This project is part of a regional metallogenic study by Höy and is the basis for a detailed examination of mineral deposits and galena-lead isotopes in the area.

Thirty-two mineral occurrences were visited and sampled and a number were mapped. This work, the descriptions and the classification scheme of Preto and Dickie (1984), and the regional geology of Schiarizza, *et al.* (1984) form the basis for the data in Table 1. The occurrences are classified as: vein, stratiform, disseminated, polymetallic volcanogenic (Kuroko), basic volcanogenic ('Cyprus'), replacement, or of unknown origin. They occur mainly in rocks of the Eagle Bay Formation. These rocks include limestone, phyllite, siliceous schist, sericitic schist, and chloritic schist; many of the schists appear to be volcanic in origin. Galena-lead isotope analyses on deposits listed in Table 1 should more clearly define ages of some of the deposits and host rocks, and allow a better interpretation of the tectonic and metallogenic evolution for deposits and rocks in the Eagle Bay Formation.

The deposits and occurrences studied are located on Figure 15, a generalized geological map from Schiarizza, *et al.* (1984). Some deposits have readily available published descriptions (for example, Rexspar; Preto, 1978) but for most, assessment reports are the best source of information. The Birk Creek area is described in the following; the occurrences are of particular interest because they are demonstrably stratabound. Locally they contain significant concentrations of pyrite with chalcopyrite, sphalerite, and galena. Other deposits in the table will be described later.

BIRK CREEK AREA

INTRODUCTION

The Birk Creek area, 3 kilometres west of North Barriere Lake, is accessible from the main logging road to North Barriere Lake which

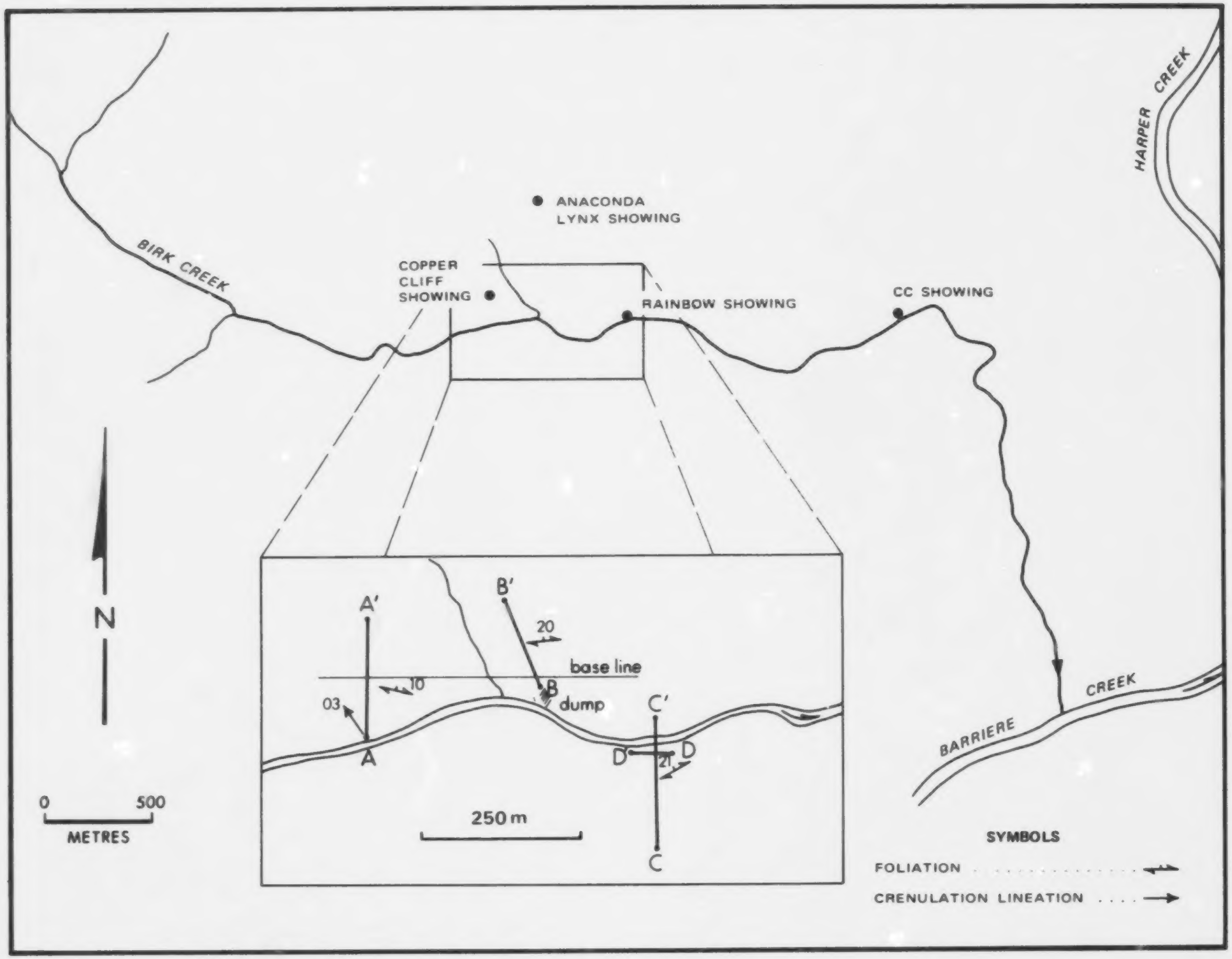

ANACONDA LYNX SHOWING
BIRK CREEK
COPPER CLIFF SHOWING
RAINBOW SHOWING
CC SHOWING
HARPER CREEK
BARRIERE CREEK
N
0
500
METRES
A'
A
03
10
B'
B
20
base line
dump
C'
C
D'
D
21
250 m
SYMBOLS
FOLIATION
CRENULATION LINEATION

Figure 16. Birk Creek area showing location of sections A-A', B-B', C-C', and D-D'.

TABLE 1
DATA FOR DEPOSITS STUDIED IN THE ADAMS PLATEAU AREA

MAP NO.	DEPOSIT NAME	LAT N	LONG W	UNIT[1]	DEPOSIT TYPE[2]	STATUS[3]	AGE[4]
03	CHU CHUA	51.38	120.07	UFE	CYPRUS: Cu Zn	R	M
04	ENARGITE	51.35	119.99	EBPI	VEIN: Pb Ag Cu Zn	P	M
05	FOGHORN	51.54	119.93	EBFq	VEIN: Ag Pb Zn Au Ag	P	L
06	AGATE BAY	51.08	119.75	EBAa	VEIN: Zn Pb Ag Cu	S	L
07	BECA (TOM)	51.05	119.71	EBAa	KUROKO: Cu Pb Zn Au Ag	P	D
08	BIRK CREEK	51.33	119.90	EBAa	KUROKO: Pb Zn Cu	P	D
09	BROKEN RIDGE	51.35	119.88	EBAa	STB & DIS: Pb Zn Cu	S	D
10	HARPER CREEK	51.34	119.85	EBAa	STB & DIS: Cu Pb Ag	S	D
11	HOMESTAKE	51.11	119.83	EBAa	MASSIVE: Ba Ag Zn Pb Cu Au	P	D
12	FORTUNA	51.01	119.71	EBAa	UNKNOWN: Cu Pb Zn	S	D
13	JOE (GLEN)	51.37	119.93	EBAa	VEIN: Pb	P	D
14	LYDIA	51.52	119.94	EBAa	MASSIVE: Pb Ag Cu	S	D
15	REA GOLD	51.13	119.81	EBAf?	VOLC: Au Ag Pb Zn Cu	R	L
16	REXPAR	51.57	119.90	EBAf	VOLC: U F	R	D
17	ART	51.10	119.95	EBSa	UNKNOWN: Pb	S	O
18	LUCKY COON	51.07	119.60	EBG	STRATIFORM: Ag Pb Zn	P	O
19	TWIN MOUNTAIN	51.13	119.80	EBG	MASSIVE: Ag Pb Zn Cu Au Ba	S	O
20	BOWLER CREEK	51.01	119.48	EBG	STB & DIS: Unknown	S	O
21	JUNE (KAJUN)	51.26	119.80	EBGp	STF & VEIN: Ag Pb Zn Cu	S	O
22	B.C. (ZINC 1)	51.01	119.52	EBGs	MASSIVE: Cu Ag Pb Zn Fe Mo	R	O
23	ELSIE	51.07	119.60	EBGs	UNKNOWN: Pb Zn Ag Au	P	O
24	KING TUT	51.07	119.60	EBGs	UNKNOWN: Ag Pb Zn Au	P	O
25	MOSQUITO KING	51.06	119.52	EBGs	STF & REPL: Pb ZN Ag Cu	P	O
26	PET	51.05	119.53	EBGs	UNKNOWN: Pb Zn	S	O
27	SPAR (FLUORINE)	51.06	119.54	EBGs	STF: Pb Zn Ag Cu Mo Au	P	O
28	WHITE ROCK	51.30	119.91	EBGt	UNKNOWN: Ag Zn Pb Cu	P	O
29	GRIZZLY	51.29	119.76	SDQ	UNKNOWN	S	E
30	BET	51.29	119.74	SDQ	DIS: Cu Ni Pb Zn	S	E
31	RED TOP	51.64	119.86	-	STF & DIS: Cu Pb Zn Ag Au	S	?
32	FLUKE (SAUL)	51.06	119.25	-	REPL: Cu Ag Pb Zn	S	?
33-37	ORELL 1-5	51.04	119.51	-	VEIN & DIS: Pb Zn Cu	S	?
38	UTAH PROSPECT	51.10	119.30	-	VEIN: Zn Pb	S	?

[1] Units are described in Table 2

[2] VOLC - volcanogenic, STB - stratabound, STF- stratiform, DIS - disseminated, REPL - replacement

[3] R - reported reserves, P - past producer, S - showing

[4] M - Mississippian, L - Devonian and/or Mississippian, D - Devonian, O - Devonian and/or older, E - Lower Cambrian and/or Hadrynian (Eocambrian ?), ? - Unknown

branches north from the road between Barriere and East Barriere Lake. The showings (Fig. 16) are accessible by a trail that follows the northeast side of Birk Creek. Several properties (Copper Cliff, May, Anaconda, Lynx, Cc, Bet, and Rainbow) occur in the area. These showings were discovered in the 1920's and are marked by small adits and dumps. In most cases the original names cannot be assigned unequivocally to individual workings.

From 1938 to 1940, 234 tonnes of ores were extracted from the Anaconda-Iron Cap property (MINFILE No. 082M-067, 1984); 6 500 grams of gold, 13 500 grams of silver, and 4 810 kilograms of copper were recovered but only an old dump (Fig. 16) remains from this activity.

TABLE 2
HOST UNITS OF MINERAL DEPOSITS EXAMINED IN THE ADAMS PLATEAU AREA
(Symbols in brackets after the age are the codes used in the age column in Table 1)

EAGLE BAY FORMATION

MISSISSIPPIAN (M)

EBPl	Limestone in a phyllite, slate, and interbedded siltstone, sandstone, and grit sequence. The one deposit in this unit (Enargite) is adjacent to the lower structural division of the Fennell Formation (lFu) which consists of chert, cherty argillite, slate, phyllite, metabasalt, gabbro, and diorite

DEVONIAN AND/OR MISSISSIPPIAN (L)

EBFq	Cherty quartzite, adjacent to a feldspathic phyllite unit (EBFf), which is derived from intermediate to felsic tuff and volcanic breccia

DEVONIAN (D)

EBAa	Sericitic phyllite and sericitic chlorite, quartz phyllite derived from intermediate volcanic and volcaniclastic rocks that include pyritic feldspathic and coarsely fragmental varieties; chlorite schist occurs locally. Some deposits in EBAa are adjacent to green chloritic phyllite, siltstone, limestone, and quartzite (EBu) which is possibly older than Devonian
EBDF	Feldspar porphyry, feldspathic phyllite, and metavolcanic breccia

DEVONIAN AND/OR OLDER (O)

EBSs	Phyllitic sandstone, grit, phyllite, and quartzite; locally limestone, dolostone, green chloritic phyllite, and sericitic quartz phyllite
EBG	Calcareous chlorite schist and fragmental schist derived largely from mafic to intermediate volcanic and volcaniclastic rocks; lesser amounts of limestone, quartzite, and phyllite
EBGp	Dark grey phyllite, calcareous phyllite, and limestone; lesser amounts of rusty-weathering carbonate-sericite-quartz phyllite are also associated with some of the deposits
EBGs	Grey siliceous and/or graphitic phyllite, calcareous phyllite, limestone, calc-silicate rock, cherty quartzite, and some chlorite and sericite-quartz schist
EBGt	Tshinakin limestone in massive, light grey, finely crystalline limestone and dolostone

LOWER CAMBRIAN AND/OR HADRYNIAN (E)

SDQ	Quartzite, micaceous quartzite, and phyllite; locally, calcareous phyllitic carbonate and green chloritic schist

Northwestern Explorations Ltd. drilled and trenched the property from 1952 to 1953, and Mining Corporation of Canada Ltd. were active in the area in 1966. Duncannex Resources Ltd. rehabilitated the trenches during 1971 and 1972, and in 1976 Kennco Explorations (Western) Ltd. and Cominco Ltd. conducted geochemical surveys in the area.

The mineral occurrences are statiform massive pyrite deposits with minor chalcopyrite, sphalerite, and galena within a metamorphosed felsic to intermediate volcanic sequence.

GEOLOGICAL SETTING OF THE BIRK CREEK AREA

The Birk Creek area (Fig. 16) contains less than 5 per cent outcrop, most of which occurs in cliffs along the creek. The area is underlain by sericite schist, chlorite schist, black phyllite, and some recrystallized limestone. The units EBAa (Tables 1 and 2) have been tentatively assigned a Devonian to Mississippian age (Schiarizza, *et al.*, 1984). No direct ages have been obtained from the area, but dating of zircons from felsic metavolcanic rocks that occur to the southeast, which are correlated with those in the Birk Creek area, have yielded ages between 367 and 379 Ma (Preto, 1981). Mississippian ages were obtained from conodonts found in limestone pods (Preto, 1981). These units have been regionally metamorphosed to greenschist facies.

A well-developed foliation, locally parallel to bedding, strikes east-west and dips variably to the south and north. A superimposed north-striking, shallow east-dipping crenulation cleavage is pronounced in outcrops near the creek (Fig. 17). Although the area is strewn with quartz monzonite boulders, the nearest known outcrop of such rocks is in the Cretaceous Baldy batholith, 2.5 kilometres to the north. Most mineralization on the property appears to be stratabound and syngenetic and, consequently, not related to the later Cretaceous intrusion.

Two stratigraphic sections, A-A', B-B', and a longitudinal section D-D' crossing the section C-C', are shown on Figures 16, 17, and 18, and are described in the following paragraphs.

Section A-A'

A cliff section is exposed from an elevation of 970 metres at the creek to 1 102 metres up section. It consists dominantly of quartz-eye sericite schist (Fig. 17). The strike of foliation varies from 265 to 290 degrees and dips 5 to 20 degrees to the north. The overall minimum thickness (perpendicular to foliation, which is approximately coincident with bedding) is 175 metres (Fig. 17); both ends of the section are covered. At the base of the section the schists contain 15 per cent quartz and plagioclase phenocrysts (maximum size, 2 millimetres) in a quartz-muscovite-plagioclase matrix. The plagioclase is altered to

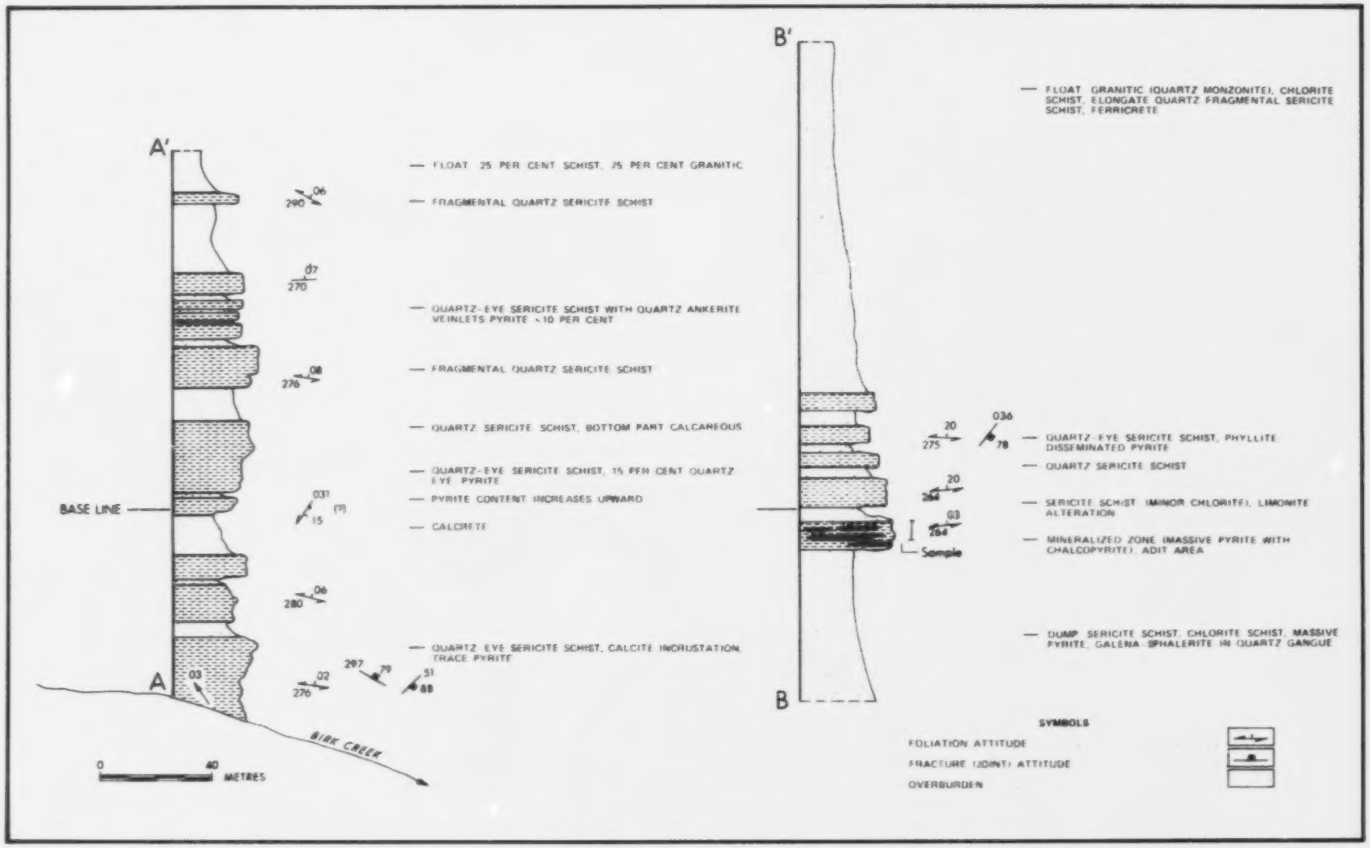

A'
A
B'
B
BASE LINE
FLOAT 25 PER CENT SCHIST, 75 PER CENT GRANITIC
FRAGMENTAL QUARTZ SERICITE SCHIST
QUARTZ-EYE SERICITE SCHIST WITH QUARTZ ANKERITE VEINLETS PYRITE <10 PER CENT
FRAGMENTAL QUARTZ SERICITE SCHIST
QUARTZ SERICITE SCHIST, BOTTOM PART CALCAREOUS
QUARTZ-EYE SERICITE SCHIST, 15 PER CENT QUARTZ EYE PYRITE
PYRITE CONTENT INCREASES UPWARD
CALCRETE
QUARTZ EYE SERICITE SCHIST, CALCITE INCRUSTATION, TRACE PYRITE
290 06
270 07
276 08
031 15 (?)
280 06
276 02
297 79
51 88
03
BIRK CREEK
0 40 METRES
FLOAT GRANITIC (QUARTZ MONZONITE), CHLORITE SCHIST, ELONGATE QUARTZ FRAGMENTAL SERICITE SCHIST, FERRICRETE
QUARTZ-EYE SERICITE SCHIST, PHYLLITE DISSEMINATED PYRITE
QUARTZ SERICITE SCHIST
SERICITE SCHIST (MINOR CHLORITE), LIMONITE ALTERATION
MINERALIZED ZONE (MASSIVE PYRITE WITH CHALCOPYRITE) ADIT AREA
DUMP SERICITE SCHIST, CHLORITE SCHIST, MASSIVE PYRITE, GALENA SPHALERITE IN QUARTZ GANGUE
275 20
036 78
264 20
264 03
Sample
SYMBOLS
FOLIATION ATTITUDE
FRACTURE (JOINT) ATTITUDE
OVERBURDEN

Figure 17. Detailed sections A-A', B-B' from the north side of Birk Creek (sections about 350 metres apart, see Fig. 16).

calcite, but up section this alteration is not apparent as the plagioclase content decreases. Autolithic fragmental units (average fragment size, 1.5 millimetres) occur locally.

Disseminated pyrite with an average grain size of 0.5 millimetre constitutes up to 8 per cent of the rock. Trace amounts of interstitial chalcopyrite are present in the pyrite. No markedly sulphide-rich horizons were observed.

Section B-B'

This section (Figs. 16 and 17) passes close to several old workings. Exposure is limited to a few outcrops and the collars of two slumped adits. A well-developed foliation, parallel to compositional layering, trends 265 to 275 degrees and dips gently north (5 to 20 degrees). Observable bedrock is composed of quartz-sericite and chlorite schist with limonite-altered pyrite-rich layers, and minor laminated black phyllites. Thin sections of the schists show zones with elongated fragments (up to 3 millimetres) of polycrystalline quartz grains.

Disseminated pyrite is present throughout much of the section. Silicified massive pyrite lenses with minor chalcopyrite were observed within an 8-metre section near the old adits. The pyrite is euhedral, but fragmented, and associated with chalcopyrite which generally occurs at the borders of the pyrite grains. Material observed on a dump in the immediate area contains similar mineralization, as well as a few blocks of vein quartz with blebs of sphalerite and galena. The latter type of mineralization was not observed in outcrop.

Sections C-C' and D-D'

Sections C-C' and D-D' (Figs. 16 and 18) cross a major showing along a cliff section on the south side of Birk Creek. Three short accessible adits, about 9 metres long, parallel a major joint direction (012 degrees). Other workings in the immediate vicinity have been flooded by the creek and are observable when water levels are low (Preto, personal communication, 1984). An east-west longitudinal section (Fig. 18) follows Birk Creek and illustrates the distribution of lithologies, mineralization, and workings.

A recrystallized medium-grained limestone with disseminated quartz grains and pods of coarsely crystalline white calcite crops out at the east end of Figure 18. Minor micaceous-rich layers occur in the unit. The limestone unit is in fault contact with generally contorted, sulphide-rich sericite schist to the west.

Sulphides occur as massive pods (up to 1 metre thick), as layers (up to 10 centimetres thick), and as fragments in silicified breccia. Sulphide

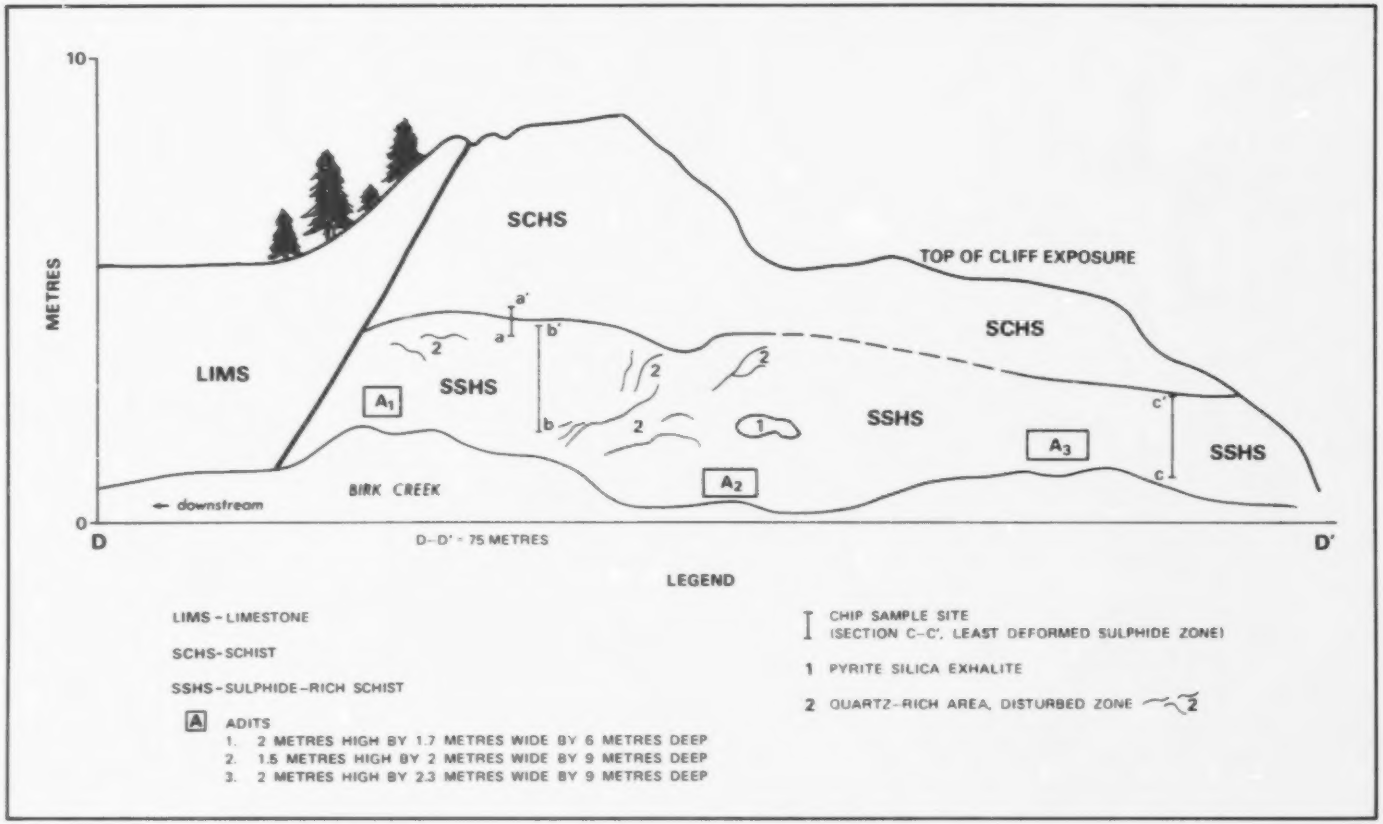

10
METRES
0
D
D'
D–D' = 75 METRES
TOP OF CLIFF EXPOSURE
SCHS
SCHS
LIMS
SSHS
SSHS
SSHS
A1
A2
A3
a'
a
b'
b
c'
c
1
2
2
2
2
BIRK CREEK
← downstream
LEGEND
LIMS - LIMESTONE
SCHS - SCHIST
SSHS - SULPHIDE-RICH SCHIST
A ADITS
1. 2 METRES HIGH BY 1.7 METRES WIDE BY 6 METRES DEEP
2. 1.5 METRES HIGH BY 2 METRES WIDE BY 9 METRES DEEP
3. 2 METRES HIGH BY 2.3 METRES WIDE BY 9 METRES DEEP
CHIP SAMPLE SITE (SECTION C–C', LEAST DEFORMED SULPHIDE ZONE)
1 PYRITE SILICA EXHALITE
2 QUARTZ-RICH AREA, DISTURBED ZONE

Figure 18. Sketch of section D-D', looking south, showing location of major lithologic units, sulphides, and adits.

mineralization, exposed in the centre of Figure 18 is composed mainly of well-formed but disrupted pyrite grains (average size, 2.5 millimetres across) with minor chalcopyrite in an ankeritic quartz matrix. This unit is interpreted to be a pyrite-silica exhalite.

Quartz-eye sericitic schist (with polycrystalline quartz-eyes up to 6 millimetres across) and carbonaceous quartz schist make up 20 per cent of the disturbed zone on Figure 18. Minor malachite stains the schists. In the western part of the section the sulphide horizons, with the same composition described previously, are well layered (layers are 8 centimetres thick over an exposed thickness of 3.5 metres). Attitudes of layering and coincident foliation are the same as those observed in the limestone.

The upper part of the cliff on Figure 18 is sulphide-poor sericite schist which is not as contorted as the underlying unit. Thus the exposed sulphide-rich section is about 4.5 metres thick (3 metres true thickness) from Birk Creek to the contact at the top of the cliff. Scant exposures north and south of the section on Figure 18 indicate that sericitic schist is abundant in the area. One other old working was observed 15 metres south of the cliff section. Dump material from this working contains traces of sphalerite, galena, and chalcopyrite in a vein-like quartz gangue. The relationship between the mineralization and the host schists cannot be defined because of poor exposure.

CONCLUSIONS

The three sections presented give an overview of the variety of lithologies and the general setting of the Birk Creek showings. The sections cannot be correlated closely but there are at least two silicified zones containing massive pyrite with minor chalcopyrite in a quartz sericite schist host. The sphalerite and galena that occur in quartz gangue are probably from veins.

In general, the units in section A-A' and B-B' dip to the northeast, whereas those in section C-C' and D-D' dip to the southeast. These dips define an east-west-trending antiform. The antiform is probably a late generation open fold with its axial plane parallel to a pronounced crenulation cleavage, similar to late structures identified by Preto (1979). Early, mesoscopic, recumbent isoclinal folds, with axial planes parallel to the pronounced schistosity, and axes plunging parallel to the mineral lineation, probably indicate larger structures which would control the distribution of the stratiform mineralized zones (Preto, personal communication, 1984).

REFERENCES

Preto, V. A. (1978): Setting and Genesis of Uranium Mineralization at Rexspar, *C.I.M.*, Bull., Vol. 71, No. 800, pp. 82-88.

.... (1979): Barriere Lakes-Adams Plateau Area (82L/13E; 82M/4, 5W; 92P/1E, 8E), *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1978, Paper 1979-1, pp. 31-37.

.... (1981): Barriere Lakes-Adams Plateau Area (82M/4, 5W; 92P/1E), *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1980, Paper 1981-1, pp. 15-23.

Preto, V. A. and Dickie, G. J. (1984): Mineral Deposits of the Adams Lake-Barriere Area, *C.I.M. District 6 Annual Meeting*, Abstract, Kamloops.

Preto, V. A., McLaren, G. P., and Schiarizza, P. A. (1980): Barriere Lakes-Adams Plateau Area (82L/13E, 82M/4, 5W; 92P/1E, 8E), *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1979, Paper 1980-1, pp. 28-36.

Schiarizza, P. A., Preto, V. A., McLaren, G. P., Diakow, L. J., and Forster, D. (1984): Geology of the Adams Plateau-Clearwater Area, *B.C. Ministry of Energy, Mines & Pet. Res.*, Preliminary Map 56.

Wojdak, P. J. (1976): Geological, Geochemical, and Trenching Report on Bet Mineral Claims, *B.C. Ministry of Energy, Mines & Pet. Res.*, Assessment Report 6202.

HILTON MASSIVE SULPHIDE DISCOVERY (REA GOLD), JOHNSON CREEK-ADAMS LAKE AREA

(82M/4W)

By G.P.E. White

INTRODUCTION

In October, 1983, prospectors A. Hilton and R. Nicholl, both of Kamloops, discovered a massive sulphide showing in the Adams Plateau area. The property was optioned to Rea Gold Corporation, and in turn to Corporation Falconbridge Copper. Work by Falconbridge has identified 120 000 drill-indicated tonnes grading 18.2 grams gold per tonne, 141.2 grams silver per tonne, 0.85 per cent copper, 4.11 per cent zinc, and 3.67 per cent lead from two massive sulphide lenses. The deposit is not fully outlined, therefore, additional reserves are considered possible.

The showing, which is on the AR-HN mineral claims, is located 98 kilometres northeast of Kamloops and 3.7 kilometres southwest of the west end of Johnson Creek, at an elevation of 1 475 metres. Access to the property is via logging roads one hour distant from the Barriere and Chase areas.

GENERAL GEOLOGY

The accompanying map (Fig. 19) of the area is underlain by 7 300 metres of apparent stratigraphic thickness of mafic to felsic volcanic rocks with intercalated sedimentary horizons. The regional schistosity strikes 140 degrees and dips 40 degrees to the northeast; the formations are overturned.

EAGLE BAY FORMATION (MISSISSIPPIAN AND OLDER)

The Eagle Bay Formation in the mapped area has been divided into two units by Schiarizza, *et al.* (1984): a Devonian and/or older mafic volcanic; and a Devonian and/or Mississippian felsic volcanic unit. Regional deformation increases in intensity on the eastern edge of the mapped area and the original nature of the mafic volcanic rocks is obscured at these localities.

Devonian (?) and/or Older (?) (EBG)

The lower unit in the mapped area consists of approximately 4 300 metres of mafic volcanic rocks; there is an increasing amount of intercalated limestone near the stratigraphic base of the section in the northeastern

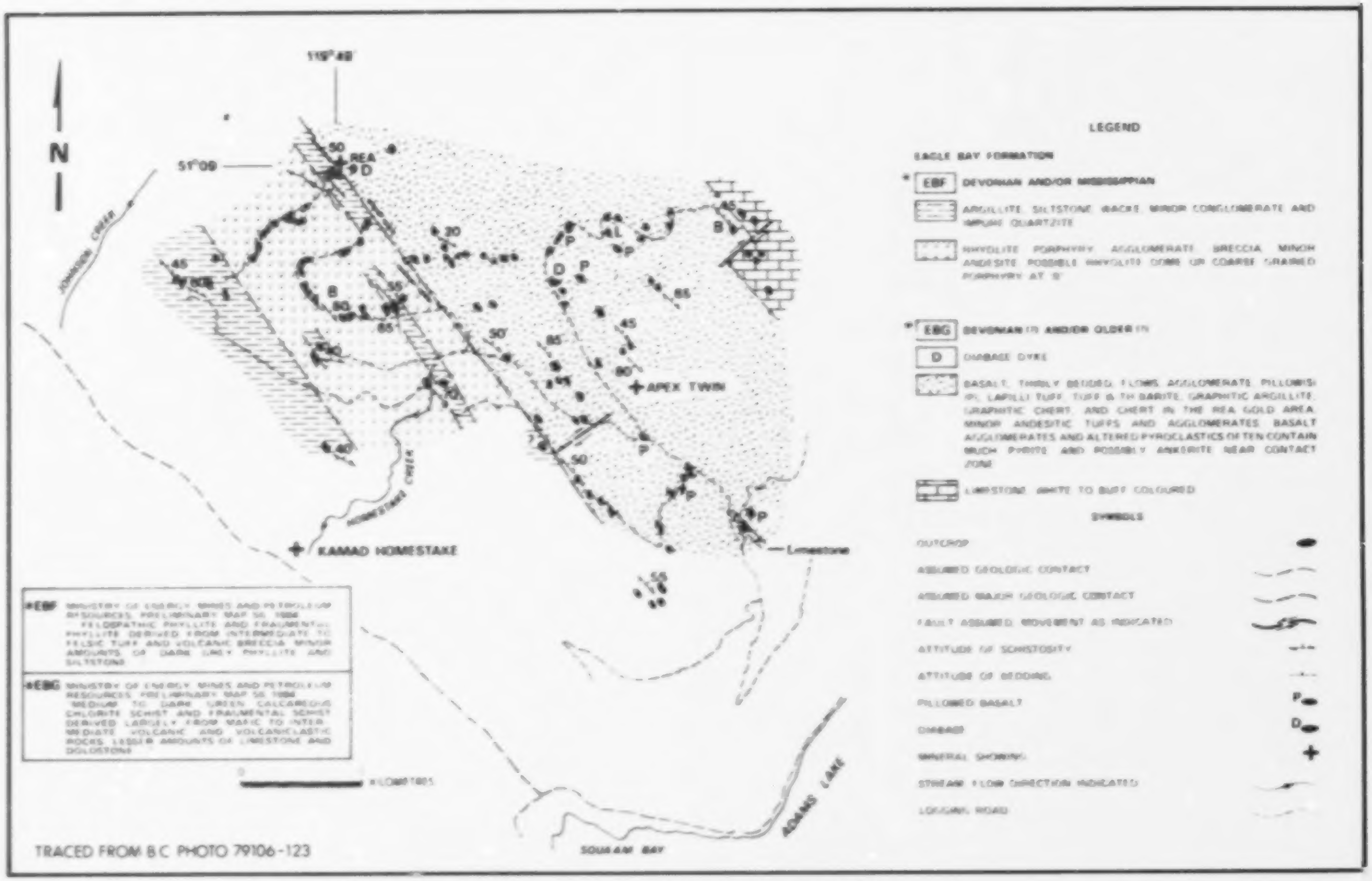

119°48'
51°09'
N
REA
D
JOHNSON CREEK
HOMESTAKE CREEK
KAMAD HOMESTAKE
APEX TWIN
Limestone
SQUAAM BAY
ADAMS LAKE
*EBF MINISTRY OF ENERGY, MINES AND PETROLEUM RESOURCES, PRELIMINARY MAP 56, 1984. FELDSPATHIC PHYLLITE AND FRAGMENTAL PHYLLITE DERIVED FROM INTERMEDIATE TO FELSIC TUFF AND VOLCANIC BRECCIA. MINOR AMOUNTS OF DARK GREY PHYLLITE AND SILTSTONE
*EBG MINISTRY OF ENERGY, MINES AND PETROLEUM RESOURCES, PRELIMINARY MAP 56, 1984. MEDIUM TO DARK GREEN CALCAREOUS CHLORITE SCHIST AND FRAGMENTAL SCHIST DERIVED LARGELY FROM MAFIC TO INTERMEDIATE VOLCANIC AND VOLCANICLASTIC ROCKS. LESSER AMOUNTS OF LIMESTONE AND DOLOSTONE
0
KILOMETRES
TRACED FROM B.C. PHOTO 79106-123
LEGEND
EAGLE BAY FORMATION
* EBF DEVONIAN AND/OR MISSISSIPPIAN
ARGILLITE, SILTSTONE, WACKE, MINOR CONGLOMERATE AND IMPURE QUARTZITE
RHYOLITE PORPHYRY, AGGLOMERATE, BRECCIA, MINOR ANDESITE, POSSIBLE RHYOLITE DOME OR COARSE GRAINED PORPHYRY AT 'B'
* EBG DEVONIAN (?) AND/OR OLDER (?)
D DIABASE DYKE
BASALT, THINLY BEDDED, FLOWS, AGGLOMERATE, PILLOWS (P), LAPILLI TUFF, TUFF & TH BARITE, GRAPHITIC ARGILLITE, GRAPHITIC CHERT, AND CHERT IN THE REA GOLD AREA. MINOR ANDESITIC TUFFS AND AGGLOMERATES. BASALT AGGLOMERATES AND ALTERED PYROCLASTICS OFTEN CONTAIN MUCH PYRITE AND POSSIBLY ANKERITE NEAR CONTACT ZONE
LIMESTONE, WHITE TO BUFF COLOURED
SYMBOLS
OUTCROP
ASSUMED GEOLOGIC CONTACT
ASSUMED MAJOR GEOLOGIC CONTACT
FAULT ASSUMED, MOVEMENT AS INDICATED
ATTITUDE OF SCHISTOSITY
ATTITUDE OF BEDDING
PILLOWED BASALT
DIABASE
MINERAL SHOWING
STREAM, FLOW DIRECTION INDICATED
LOGGING ROAD

Figure 19. Geology of the Hilton-Rea-Falconbridge area.

part of the area. The limestone is white to buff, fine grained, and crystalline; it often forms prominent hills. The mafic volcanic rocks are chiefly pillow lavas, agglomerates, flows, and basaltic to andesitic tuffs. Near the stratigraphic top of this section layers have sharp contacts and are from 4 to 20 metres thick. During the late stages of volcanic activity, massive sulphides were deposited, along with pyritized flows and agglomerate beds which are commonly overlain by andesitic to basaltic tuff.

Diabase dykes with pyrite, and pyritic quartz veins were noted at the Hilton and at the Apex sites (Fig. 20).

Minor, localized depositional hiatuses may exist at the Hilton site between the mafic volcanic rocks and overlying sedimentary and felsic volcanic rocks, although no stratigraphic discordance was observed in the field.

Devonian and/or Mississippian (EBF)

Within the area mapped, this unit consists of approximately 3 000 metres of strata, of which 60 per cent is felsic volcanic rocks with some andesite, and 40 per cent is intercalated sedimentary rocks.

At the base, overlying unit EBG, is a sedimentary unit consisting of graphitic and commonly finely laminated argillite, wacke, conglomerate, and chert. The contact is locally gradational, commonly faulted, and perhaps locally disconformable. Soft sediment and slump features occur in the chert and argillite, which are in contact with andesite or basalt tuff of the underlying mafic unit.

The felsic volcanic part of the section consists of rhyolite breccia, agglomerate and tuff, some andesite agglomerate and breccia, intercalated argillite, siltstone, wacke, and some impure quartzite, the latter cropping out in the southwest corner of the area mapped.

The rhyolite units are usually feldspar porphyritic with frequent flow breccia. Breccia fragments are generally closely packed and fragments range up to 25 centimetres in maximum dimension. Andesite is commonly agglomeratic with sheared, elongated clasts.

HILTON SHOWING

The following descriptions refer to those rock units on the Hilton ground as seen in drill core, in trenches, and in surface outcrop. The complexity of the Hilton discovery is apparent in the abrupt mineralogical and lithological changes visible in trenches over a strike distance of roughly 300 metres, as well as in the variety of relationships observed between massive sulphides and overlying strata. A representative diagrammatic section of the massive sulphide setting is presented on Figure 20.

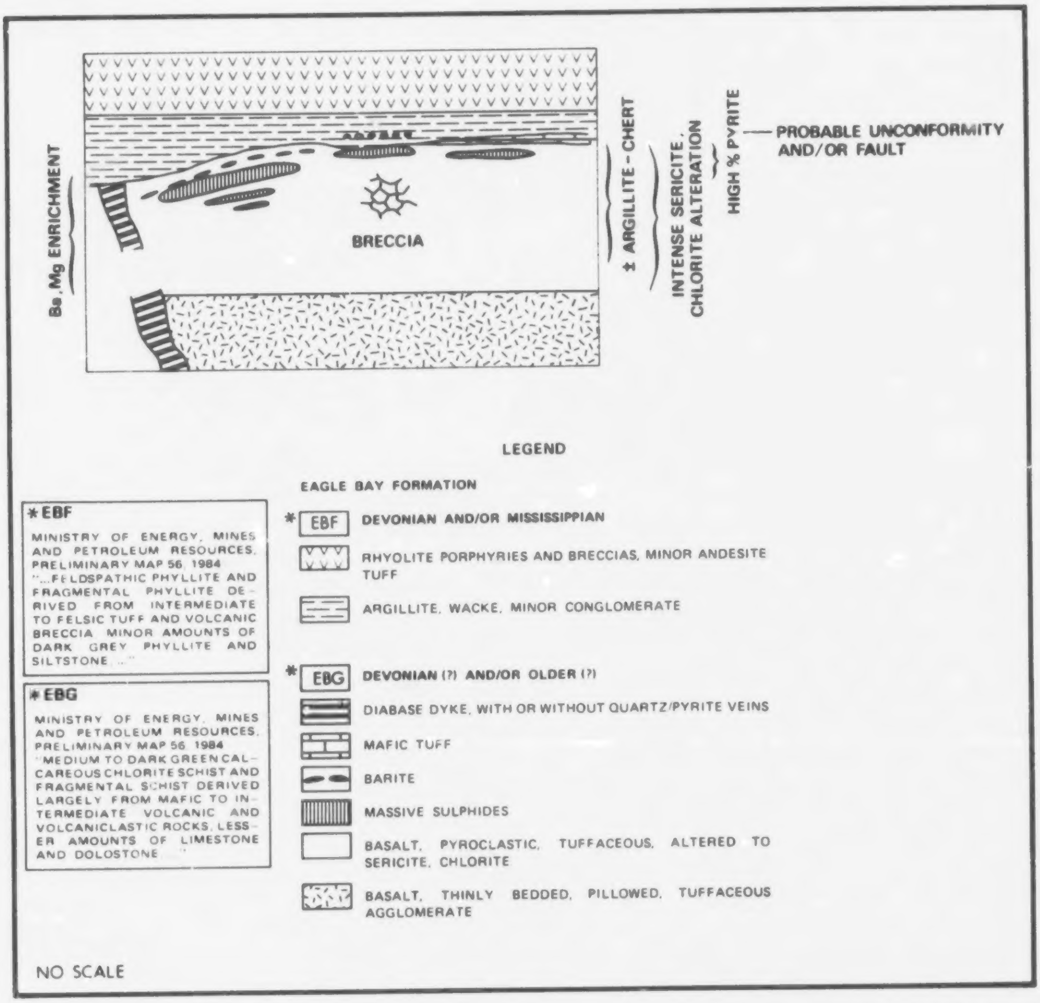

Ba, Mg ENRICHMENT
BRECCIA
± ARGILLITE - CHERT
INTENSE SERICITE, CHLORITE ALTERATION
HIGH % PYRITE
PROBABLE UNCONFORMITY AND/OR FAULT
LEGEND
EAGLE BAY FORMATION
* EBF DEVONIAN AND/OR MISSISSIPPIAN
RHYOLITE PORPHYRIES AND BRECCIAS, MINOR ANDESITE TUFF
ARGILLITE, WACKE, MINOR CONGLOMERATE
* EBG DEVONIAN (?) AND/OR OLDER (?)
DIABASE DYKE, WITH OR WITHOUT QUARTZ/PYRITE VEINS
MAFIC TUFF
BARITE
MASSIVE SULPHIDES
BASALT, PYROCLASTIC, TUFFACEOUS, ALTERED TO SERICITE, CHLORITE
BASALT, THINLY BEDDED, PILLOWED, TUFFACEOUS AGGLOMERATE
* EBF
MINISTRY OF ENERGY, MINES AND PETROLEUM RESOURCES, PRELIMINARY MAP 56, 1984 "...FELDSPATHIC PHYLLITE AND FRAGMENTAL PHYLLITE DERIVED FROM INTERMEDIATE TO FELSIC TUFF AND VOLCANIC BRECCIA MINOR AMOUNTS OF DARK GREY PHYLLITE AND SILTSTONE, ..."
* EBG
MINISTRY OF ENERGY, MINES AND PETROLEUM RESOURCES, PRELIMINARY MAP 56, 1984 "MEDIUM TO DARK GREEN CALCAREOUS CHLORITE SCHIST AND FRAGMENTAL SCHIST DERIVED LARGELY FROM MAFIC TO INTERMEDIATE VOLCANIC AND VOLCANICLASTIC ROCKS, LESSER AMOUNTS OF LIMESTONE AND DOLOSTONE ..."
NO SCALE

Figure 20. Diagrammatic vertical southeast-northwest section, Hilton-Rea-Falconbridge area.

The massive sulphides occur in two principal lenses, approximately at the same stratigraphic horizon; other narrow sulphide bands are usually present below the main sulphide bodies. The sulphides are hosted in mafic pyroclastic rocks which have been altered to sericite and chlorite schist. The schist has ubiquitous pyrite and may contain calcite, dolomite, and iron-rich magnesite. The sulphides are often underlain by crackle breccias with 0.5 to 4-centimetre-spaced fractures, commonly filled with pyrite, or a mixture of pyrite, arsenopyrite, galena, chalcopyrite, and sphalerite. Within the brecciated section, silicified argillite and graphitic chert are also present.

The sulphides range from fine grained, massive with a faint breccia texture, to medium grained and banded. Pyritic chert occurs stratigraphically above the massive sulphide lenses.

Minerals identified from the Hilton showing by field and laboratory methods are pyrite, arsenopyrite, sphalerite, galena, chalcopyrite, tetrahedrite-tennantite, albite, anglesite, jarosite, celsian, cymrite, barite, chlorite, goethite, and trace amounts of quartz and ilmenite. Gold has no obvious affinity with any unit; it occurs in the volcanic rocks, in barite, in the massive sulphides, and even as visible gold in fault gouge. Barite and silver commonly occur together while zinc, lead, and copper are generally associated with arsenic (I. Pirie, personal communication, 1984).

The ubiquitous pyrite occurs as fine, occasionally subhedral grains in a cherty matrix, as fine, 2-millimetre-wide stringers that are concordant with the regional schistosity, and as 3 to 4-millimetre-sized blebs also in a cherty matrix. Pyrite also occurs in 4 to 10-centimetre-long, rounded to serrate-edged fragments, that consist of agglomerated 1 to 2-millimetre pyrite grains, in a pyritiferous, altered basalt. The fragments, as well as the pyrite grains in them, are aligned in the plane of the regional schistosity. Pyrite occurs both above and below the massive sulphides but appears to be more abundant stratigraphically above the massive sulphide. In some cases, pyrite constitutes 70 per cent of the rock across 2 metres of stratigraphic thickness. The pyritiferous, altered volcanic rocks are up to 15 metres thick in the structural footwall (stratigraphic hangingwall).

One characteristic of the Hilton discovery is an abrupt change in mineralogy from trench to trench without apparent structural displacement. For example, in a trench at the southwest side of the property massive albite forms an amorphous white mass that measures 2 by 3 metres and underlies the massive sulphides; in the same trench, barite overlies the sulphides. Chert occurs more frequently in the trenches to the northwest. Celsian is not present in all trenches, and barite occurs either as individual grains or as a 3-metre-thick bed directly overlying the sulphides. Dolomite forms 1 to 2-centimetre-rounded blebs and veins in the encompassing altered volcanic rocks or with the sulphides. An iron-rich magnesite is also present throughout sections of the altered volcanic rocks as 1 to 2-millimetre-wide orange-coloured veins.

Emplacement of the massive sulphides at the end of the phase of mafic volcanic activity was accompanied by silicification, pyrite enrichment, soda enrichment (massive albite and paragonite), barite deposition (barite and celsian), and carbonatization (dolomite, iron-rich magnesite, and calcite). As indicated, the mineralogy varies over relatively short distances at the Hilton site. The brecciation and near total alteration of the hosting mafic volcanic rocks to sericite and chlorite may indicate proximity to a vent area from which extrusion of chemically varied fluids occurred within a relatively short time period.

Strata overlying the massive sulphides are as changeable as the mineralogy. For example, the massive sulphides are variably overlain by altered mafic tuff, by a grey tuffaceous mudstone, by barite, by graphitic argillite, and by 30 centimetres of fault gouge.

Sedimentary rocks overlying the mafic volcanic sequence consist of argillite, chert, wacke, and conglomerate. The argillite is frequently graphitic to thinly laminated, and the chert is graphitic with 1-millimetre or thinner, light-coloured bands. The chert is present close to the contact zone. Crossbedding in argillites and graded beds in conglomerates indicate tops to the southwest. The wacke and conglomerate beds have closely packed, rounded to subrounded, quartz and potassium feldspar grains with sericite, rutile, ankerite, plagioclase, chlorite, calcite, and paragonite in the matrix. Occasional 5-millimetre, angular clasts of argillite and occasional 4 to 5-millimetre blebs of pyrite or chalcopyrite are present in the conglomerate.

SUMMARY

On the Hilton property, an overturned, 450-metre-thick section of altered mafic volcanic rocks hosts the two massive sulphide lenses. The mineralization is accompanied by silicification or sericite, chlorite, and carbonate alteration with ubiquitous pyrite. The stratigraphic footwall is brecciated volcanic rock, and the hangingwall a sedimentary sequence that is at least 100 metres thick.

REGIONAL IMPLICATIONS

The contact between the mafic unit (EBG) to the northeast and the mainly felsic rocks to the southwest (EBF) is considered to be a prime exploration target. The Hilton deposit lies near the stratigraphic top of the mafic unit (EBG) which is commonly marked by closely packed, agglomerated fine-grained pyrite fragments in a sericite and chlorite-rich altered basalt matrix. These pyrite-enriched volcanic horizons are believed to represent the end phase of volcanic activity in the mafic volcanic unit and thus mark the stratigraphic position at which massive sulphides might have been deposited. Therefore intensely altered mafic volcanic rocks, particularly where brecciated and pyritic, are guides to exploration for similar deposits.

ACKNOWLEDGMENTS

Corporation Falconbridge Copper afforded access to drill core, trenches, and the Hilton property. Discussions of mineralogy and rock types were held with I. Pirie, J. Oliver, D. Blanchflower, and R. Shearing. Assays and mineral identity were carried out by the British Columbia Ministry of Energy, Mines and Petroleum Resources' laboratory in Victoria. Thin sections were prepared by R. Player in our Victoria office. A. Hilton was always ready with information and was most helpful.

REFERENCE

Schiarizza, P., Preto, V. A., McLaren, G. P., Diakow, L. J., and Forster, D. (1984): Geology of the Adams Plateau-Clearwater Area (82L/13; 83M/3, 4, 5, 6, 12; 92P/1, 8, 9), *B.C. Ministry of Energy, Mines & Pet. Res.*, Preliminary Map 56.

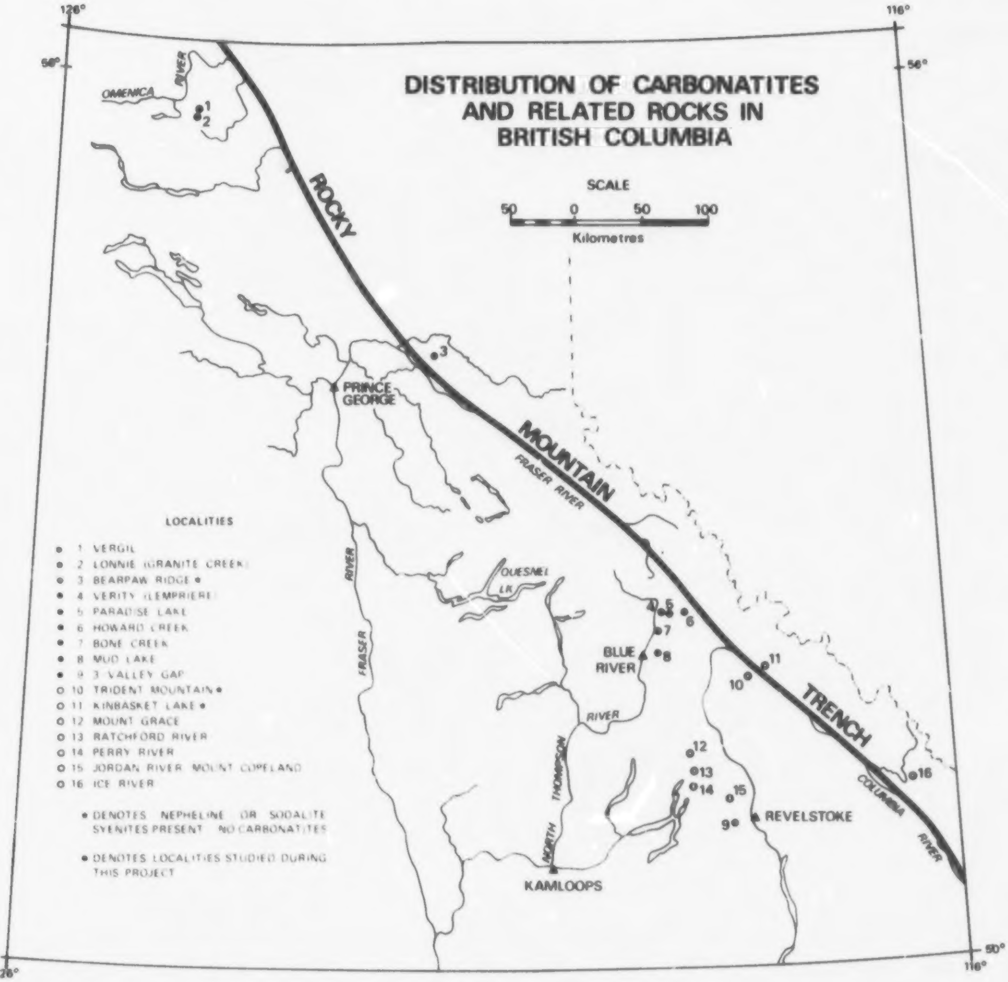

DISTRIBUTION OF CARBONATITES AND RELATED ROCKS IN BRITISH COLUMBIA
SCALE
50 0 50 100
Kilometres
126°
116°
56°
50°
ROCKY MOUNTAIN TRENCH
OMENICA RIVER
PRINCE GEORGE
FRASER RIVER
QUESNEL LK
BLUE RIVER
NORTH THOMPSON RIVER
KAMLOOPS
REVELSTOKE
COLUMBIA RIVER
LOCALITIES
● 1 VERGIL
● 2 LONNIE (GRANITE CREEK)
● 3 BEARPAW RIDGE *
● 4 VERITY (LEMPRIERE)
● 5 PARADISE LAKE
● 6 HOWARD CREEK
● 7 BONE CREEK
● 8 MUD LAKE
● 9 3 VALLEY GAP
○ 10 TRIDENT MOUNTAIN *
○ 11 KINBASKET LAKE *
○ 12 MOUNT GRACE
○ 13 RATCHFORD RIVER
○ 14 PERRY RIVER
○ 15 JORDAN RIVER MOUNT COPELAND
○ 16 ICE RIVER
* DENOTES NEPHELINE OR SODALITE SYENITES PRESENT NO CARBONATITES
● DENOTES LOCALITIES STUDIED DURING THIS PROJECT
1
2
3
5
6
7
8
9
10
11
12
13
14
15
16

Figure 21. Distribution of carbonatites and related rocks in British Columbia.

CARBONATITES AND RELATED ROCKS IN BRITISH COLUMBIA
(82L, 83D, 93I, 93N)

By J. Pell
Post-doctorate Fellow, University of British Columbia

INTRODUCTION

Carbonatites are ultramafic igneous rocks composed of more than 50 per cent carbonate minerals. They may contain significant amounts of olivine, magnetite, pyroxene, sodic amphibole, biotite, vermiculite, apatite, columbite, zircon, and pyrochlore. Carbonatites have been prospected the world over because they are commercial sources of niobium (from columbite and pyrochlore), phosphates (from apatite), rare earths, vermiculite, copper, and fluorite.

Carbonatites are often associated with other alkaline rocks such as nepheline and sodalite syenites, urtites, and ijolites (nepheline and feldspathoid-rich rocks). Metasomatic rocks (fenites) enriched in sodium and ferric iron and depleted in silica may be present along the margins of carbonatite complexes. Locally, kimberlite dykes and diatremes are associated with carbonatitic material. Occurrences of kimberlites in British Columbia will be dealt with in future studies.

A number of known carbonatite localities in British Columbia occur in a broad belt along the Rocky Mountain Trench. Most other Canadian examples occur in Quebec and Ontario, for example, Oka and Callander Bay (Currie, 1976a).

Carbonatites examined for this study were the Lonnie (Granite Creek) and Vergil prospects near Manson Creek (93N/9); the Verity (Lempriere), Paradise Lake, and Bone Creek prospects (83D/6), the Mud Lake showing (83D/3) and the Howard Creek site (83D/7) all near Blue River; and an exposure near Three Valley Gap (82L/16) in the Revelstoke area (Fig. 21). In addition, although it has no known associated carbonatites, a sodalite syenite on Bearpaw Ridge northeast of Prince George (93I/4) was also mapped. Other examples of British Columbia carbonatites and related rocks, which were not studied during this field season, are found in the vicinity of the Frenchman Cap gneiss dome, northwest of Revelstoke (Jordan River-Mount Copeland area, Fyles, 1970; Currie, 1976b; Perry River and Ratchford River, McMillan, 1970; McMillan and Moore, 1974; and Mount Grace, Hoy and Kwong, in prep.), along McNaughton Lake near the Mica Dam (Kinbasket Lake and Trident Mountain, Currie, 1976a), and in Yoho National Park, east of Golden (Ice River Complex, Currie 1975; Peterson, 1983).

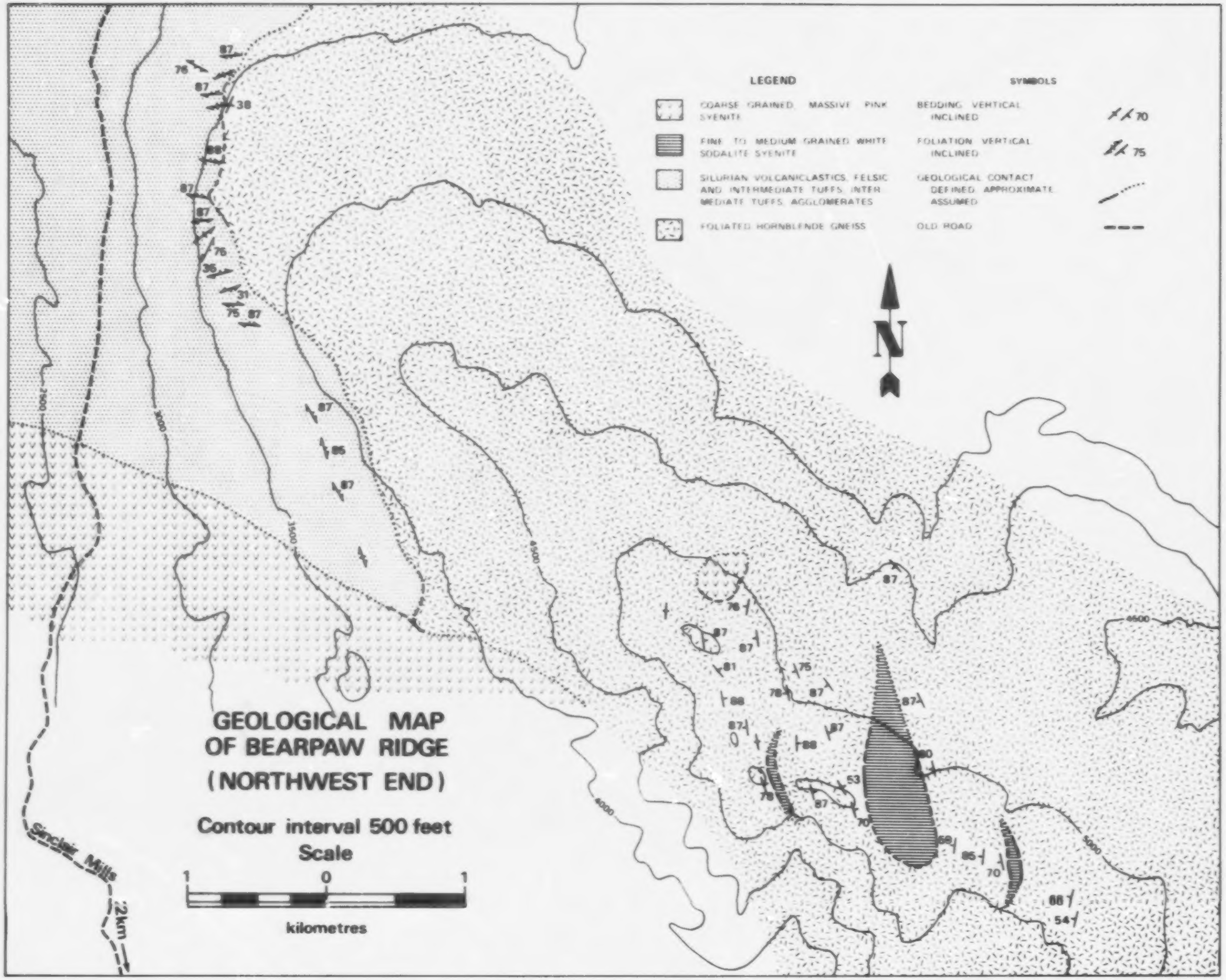

GEOLOGICAL MAP OF BEARPAW RIDGE (NORTHWEST END)
Contour interval 500 feet
Scale
1 0 1
kilometres
LEGEND
COARSE GRAINED, MASSIVE PINK SYENITE
FINE TO MEDIUM GRAINED WHITE SODALITE SYENITE
SILURIAN VOLCANICLASTICS, FELSIC AND INTERMEDIATE TUFFS, INTERMEDIATE TUFFS, AGGLOMERATES
FOLIATED HORNBLENDE GNEISS
SYMBOLS
BEDDING VERTICAL INCLINED 70
FOLIATION VERTICAL INCLINED 75
GEOLOGICAL CONTACT DEFINED, APPROXIMATE, ASSUMED
OLD ROAD
N
Sinclair Mills
2km
2500
3000
3500
4000
4500
5000

Figure 22. Geological map of Bearpaw Ridge (northern end).

GENERAL GEOLOGY

The carbonatites and related rocks studied this year were all injected into Upper Precambrian to Lower Paleozoic miogeoclinal rocks. The time of emplacement appears, in all cases, to be prior to the deformation and metamorphism associated with the Jurassic-Cretaceous Columbian orogeny. The age of the Ice River Complex has been estimated at 245 Ma using whole rock Rb/Sr analyses (Currie, 1975). Okulitch, *et al.* (1981) have dated intrusive rocks from the Mount Copeland area at 773 Ma. One U/Pb zircon date has been obtained from the Verity deposit (G. White, personal communication, 1984) which places its age at 325 Ma. Further isotopic dating is currently in progress.

All the deposits examined exhibit many similarities, but the most marked similarities occur within localities in an individual region. In the following discussion the carbonatites will be described by area.

MANSON CREEK AREA (93N/9)

Syenite, monzonite, and carbonatite occur together on both the Lonnie (Granite Creek) and Vergil claims. The two showings are located 3 kilometres apart approximately 8 kilometres east of the gold mining village of Manson Creek, 230 kilometres northwest of Prince George. Exposures are in trenches at 1 000 to 1 100 metres in elevation. Except for these trenches and along Granite Creek, outcrop is sparse.

At both Lonnie and Vergil the intrusive rocks occur in single, northwest-trending, sill-like horizons within uppermost Precambrian metasedimentary rocks. The metasedimentary rocks are part of the Wolverine Complex and have, along with the intrusive rocks, been metamorphosed to lower amphibolite facies. Within each intrusive zone the various rock units are distributed in interfingering lenses (Hankinson, 1958; Rowe, 1958; Halleran, 1980). The Lonnie (Granite Creek) carbonatite is up to 50 metres in thickness and traceable for nearly 500 metres; the Vergil showing is approximately 30 metres thick and can only be traced for a few hundred metres.

Carbonatites of two varieties are present within the Lonnie Complex; one is aegirine sovite in which the principal components are calcite, microcline, and aegirine, the other is biotite sovite with calcite, biotite, and plagioclase. Both varieties are foliated and contain apatite and pyrochlore. The biotite sovite occurs along the northeastern margin of the complex; the aegirine sovite along its southwestern margin. Feldspathic intrusive rocks, monzodiorites, monzonites, and syenites, separate the carbonatite units. These intrusive rocks consist of K-feldspar and plagioclase in varying proportions, with biotite, muscovite, and minor amounts of calcite, zircon, columbite, and ilmenorutile (Halleran, 1980). Nepheline syenite has also been recognized (Hankinson, 1958) within this suite.

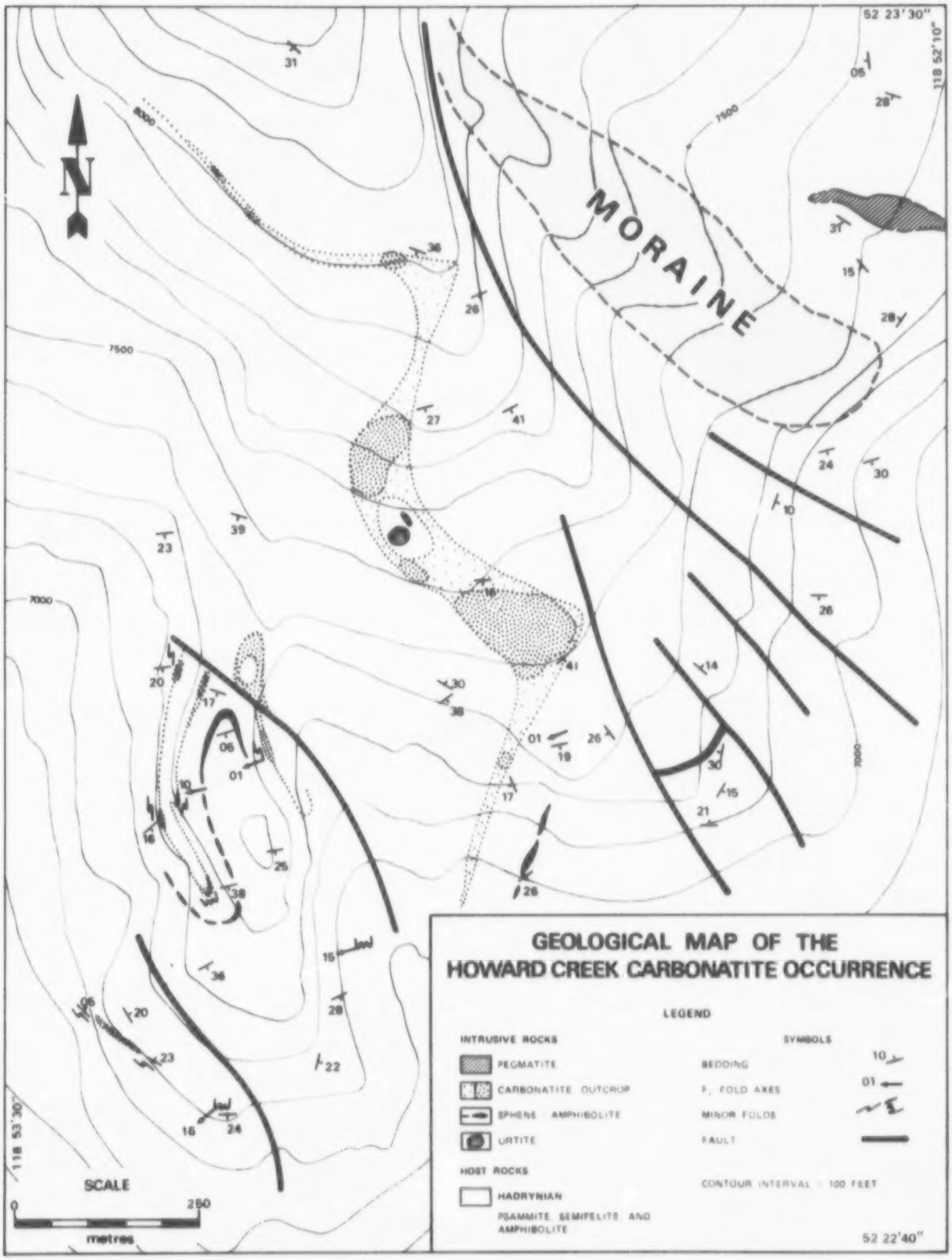

52 23'30"
118 52'10"
MORAINE
N
8000
7500
7000
31
36
26
27
41
39
23
16
41
30
38
01
19
26
17
20
17
06
01
10
16
38
25
15
36
20
06
23
16
24
22
28
26
24
30
10
26
14
30
15
21
05
28
37
15
28
118 53'30"
SCALE
0
250
metres
GEOLOGICAL MAP OF THE
HOWARD CREEK CARBONATITE OCCURRENCE
LEGEND
INTRUSIVE ROCKS
PEGMATITE
CARBONATITE OUTCROP
SPHENE AMPHIBOLITE
URTITE
HOST ROCKS
HADRYNIAN
PSAMMITE, SEMIPELITE AND AMPHIBOLITE
SYMBOLS
BEDDING
10
F, FOLD AXES
01
MINOR FOLDS
FAULT
CONTOUR INTERVAL = 100 FEET
52 22'40"

Figure 23. Geological map of the Howard Creek carbonatite occurrence.

The biotite sovite is mylonitized. To the northeast its contact with psammites and micaceous quartzites of the Wolverine Complex is not exposed; to the southwest it is in contact with fenite, that consists dominantly of aegirine, crossite, and microcline (Halleran, 1980), and interlayered sovite and fenitized metasedimentary rocks that were originally psammites and are now dominantly microcline, quartz, and aegirine.

The Vergil showing is not as well exposed as the Lonnie occurrence. Feldspathic monzonites to syenites border a lensoid layer of biotite sovite. Some mafic fenite, similar to that found at Granite Creek, occurs in the Vergil showing. The contact with host metasediments is not exposed. Fault breccia zones are abundant.

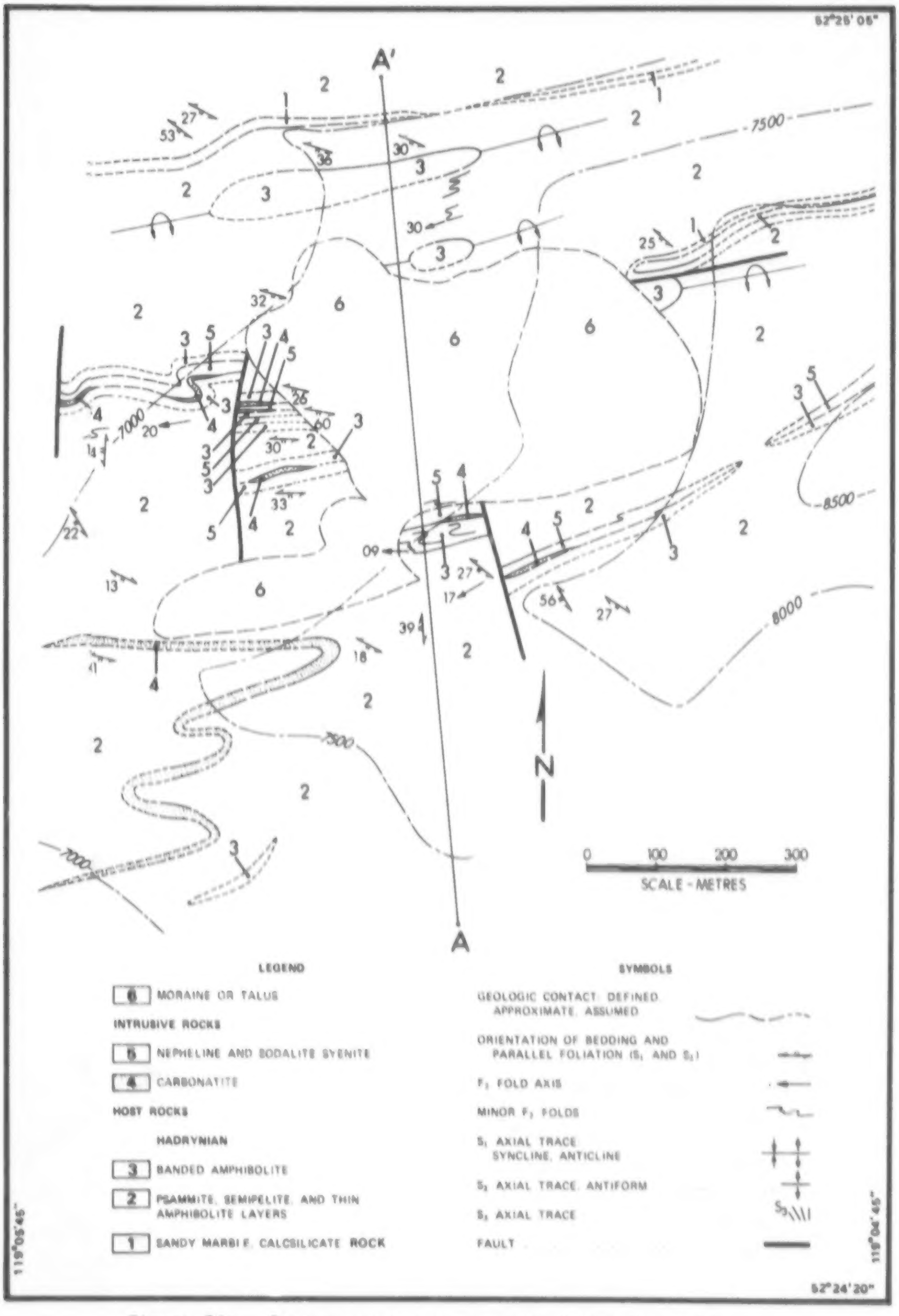
BEARPAW RIDGE (93I/4)

A body of sodalite syenite was mapped on Bearpaw Ridge in the Rocky Mountains approximately 60 kilometres northeast of Prince George. The syenite intrudes Silurian volcaniclastic rocks, which are predominantly banded felsic and intermediate tuffs and agglomerates containing limestone clasts. The syenite is massive, fine to medium grained, and white weathering. It is composed primarily of K-feldspar with varying amounts of hornblende, magnetite, and sodalite. Sodalite syenite is exposed on Bearpaw Ridge (Fig. 22) as three independent bands. Although the main bodies are roughly parallel to bedding in the volcaniclastic rocks, crosscutting dykelets were observed. Regionally, the host rocks have attained the lower greenschist facies of metamorphism; however, adjacent to the sodalite syenite, biotite is present in the Silurian rocks. Although the relationships are slightly ambiguous, it appears that the main body of sodalite syenite on Bearpaw Ridge is exposed in the core of a synform. The other two apparent layers seem to be part of a single sheet folded by the synform and now exposed on its limbs.

Another body of syenite present on Bearpaw Ridge (Fig. 22) is a massive, coarse-grained rock with a buff to pink fresh surface. In it, feldspar laths, which can be 1.5 centimetres long, are randomly oriented. Opaques, predominantly magnetite, can comprise up to 10 per cent of the rock. Unlike the sodalite syenite, this body appears to be post-orogenic; it crosscuts both the foliated hornblende gneisses of unknown age and the Silurian volcaniclastic rocks (Fig. 22).

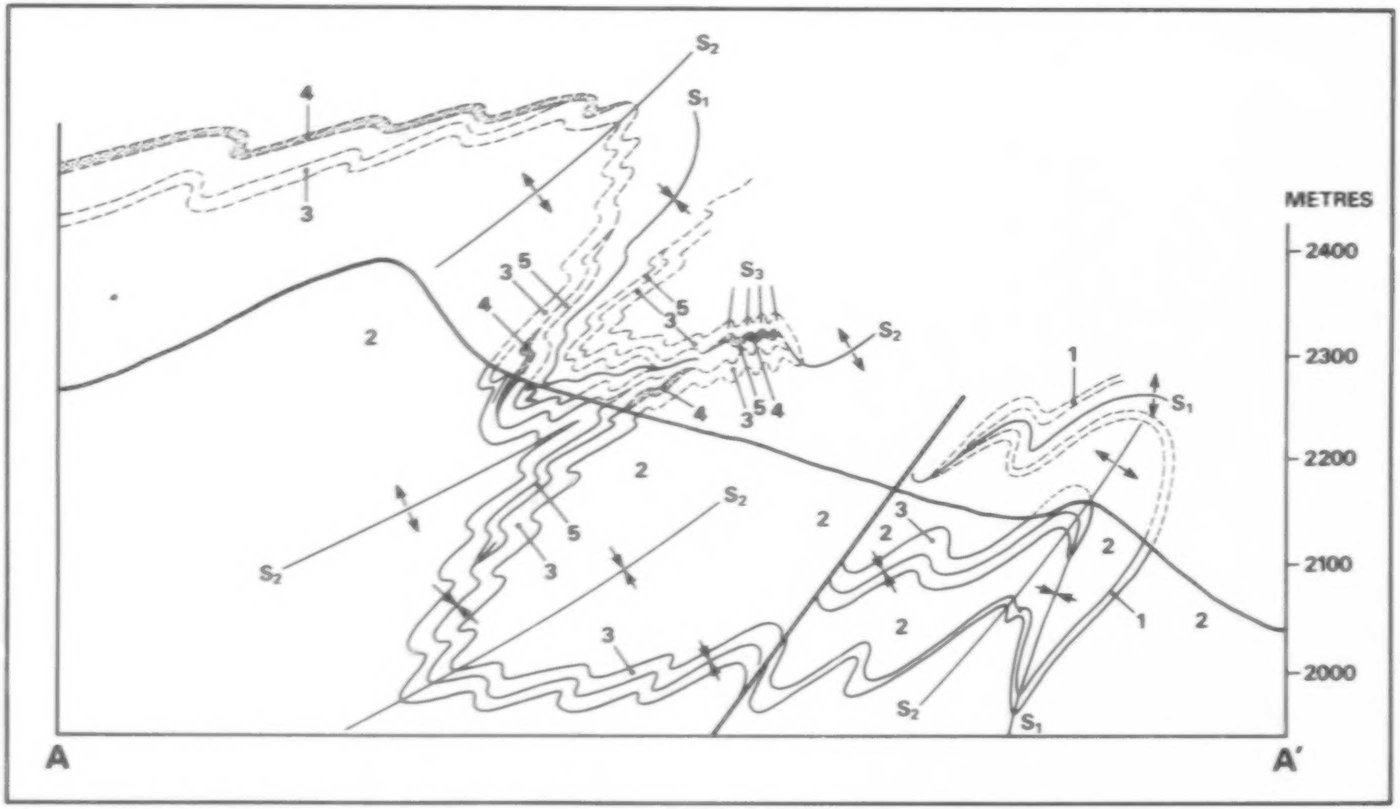
BLUE RIVER AREA (83D/3, 6, 7)

A number of carbonatite layers occur within the Semipelite-Amphibolite Division of the Hadrynian Horsethief Creek Group in the Monashee Mountains near Blue River, 250 kilometres north of Kamloops. All are bedding parallel, sill-like bodies which were intruded prior to deformation and metamorphism associated with the Columbian orogeny. The



52°25'05"
A'
A
7500
7000
8000
8500
N
0 100 200 300
SCALE - METRES
LEGEND
6 MORAINE OR TALUS
INTRUSIVE ROCKS
5 NEPHELINE AND SODALITE SYENITE
4 CARBONATITE
HOST ROCKS
HADRYNIAN
3 BANDED AMPHIBOLITE
2 PSAMMITE, SEMIPELITE, AND THIN AMPHIBOLITE LAYERS
1 SANDY MARBLE, CALCSILICATE ROCK
SYMBOLS
GEOLOGIC CONTACT: DEFINED, APPROXIMATE, ASSUMED
ORIENTATION OF BEDDING AND PARALLEL FOLIATION (S_1 AND S_2)
F_2 FOLD AXIS
MINOR F_2 FOLDS
S_2 AXIAL TRACE SYNCLINE, ANTICLINE
S_3 AXIAL TRACE, ANTIFORM
S_3 AXIAL TRACE
S_3
FAULT
119°05'45"
119°04'45"
52°24'20"

Figure 24a. Geology of the area south of Paradise Lake.



S₂
S₁
4
3
METRES
2400
2300
2200
2100
2000
3
5
4
2
S₃
5
3
S₂
1
S₁
4
3
5
4
2
S₂
2
3
2
2
3
5
S₂
3
2
1
2
S₂
S₁
A
A′

Figure 24b. Cross-section A—A', area south of Paradise Lake.

carbonatites and surrounding sedimentary rocks have been metamorphosed to upper amphibolite grade (kyanite to sillimanite zone). The Mud Lake, Bone Creek, and Verity showings (Fig. 21) occur below treeline at elevation 2 000 metres; consequently, exposure is limited. The Paradise Lake and Howard Creek carbonatites are above treeline, well exposed, and therefore could be mapped in detail (Fig. 23; Figs. 24a and 24b).

Two types of carbonatite occur within this suite (*see also* Aaquist, 1982). One is calcitic (sovite) and contains variable amounts of olivine, magnetite, apatite, zircon, and biotite or vermiculite. The second, a buff-weathering variety, is dolomitic (beforsite) with amphibole (richterite and/or tremolite), magnetite, apatite, pyrochlore, zircon, and columbite. Apatite and amphibole within the beforsite define a foliation parallel to both the edges of the carbonatite and the external schistosity. Compositional banding with alternating amphibole, apatite, and carbonate-rich layers, parallels foliation in some outcrops. At Verity, separate bands of sovite and beforsite occur. The sovite locally contains calcite and olivine crystals 2.5 to 3 centimetres in size, and clusters of magnetite crystals over 20 centimetres in diameter. Although the beforsite is not usually as coarse grained, 3 to 4-centimetre pyrochlore crystals have been found. Zircon crystals 1 to 1.5 centimetres in size occur in both the sovite and beforsite layers. At Paradise Lake apparently continuous horizons grade from sovite into beforsite. The other showings contain either sovite or beforsite but not both. Mafic fenites, 1 to 30 centimetres thick, locally separate the carbonatites and host metasedimentary rocks. The fenites may be either amphibole rich, similar to those in the Manson Creek area, or predominantly composed of biotite or vermiculite. Metasedimentary rocks adjacent to these fenites appear unaltered.

At Howard Creek urtite and sphene-bearing amphibolite (Fig. 23) are present. The sphene amphibolite can be layered and foliated or massive with dark green amphibole crystals exceeding 35 centimetres in length, and euhedral, honey-coloured sphene crystals up to 2 centimetres in size. Minor amounts of nepheline and calcite may also occur. This amphibolite is transitional at one locality to meta-ijolite or urtite, with 40 to 70 per cent coarse nepheline, 50 to 20 per cent amphibole, and 10 per cent sphene. Although the urtite and sphene amphibolite (meta-melteigite ?) are not interlayered with the carbonatite, they are presumably part of the same intrusive event.

Nepheline, sodalite, and calcareous syenites crop out in the Paradise Lake area. The syenites are foliated and medium grained; they consist of feldspar, nepheline, biotite, muscovite, calcite, zircon, and minor amounts of sodalite. They are migmatitic with massive, medium to coarse-grained, lensoid leucosomes that are predominantly composed of nepheline and sodalite. Locally, biotite sovite is interlayered with the syenites; the sovite can contain nepheline and the syenites can contain as much as 30 per cent carbonate. One zone is predominantly syenite (Figs. 24a and 24b); outward from the syenite the same horizon is prone to carbonatite development.

At both Paradise Lake and Howard Creek the carbonatites and related rocks are folded by second generation structures (Figs. 23 and 24). At Paradise Lake it is evident that these rocks are also involved in the earliest recognizable deformational event in the area (Fig. 24).

THREE VALLEY GAP AREA (82L/16)

Carbonatites are found along the Victor Lake main logging road, 3 kilometres east of Three Valley Gap, between 900 and 1 500 metres in elevation. Outcrop is limited to logging road cuts, therefore these carbonatites have not been mapped in detail. They occur as bedding parallel lenses in Hadrynian metasedimentary rocks. Both the carbonatites and host rocks have been metamorphosed to upper amphibolite grade (sillimanite zone), and the metasedimentary rocks have been extensively migmatized. The carbonatites are primarily composed of calcite, biotite, amphibole, and apatite. In places they contain feldspathic lenses similar to migmatitic leucosome. All display a well-defined biotite foliation. Amphibole-rich fenite, which locally contains zircons, separates the carbonatites from adjacent rocks. Coarse sphene crystals are developed in the pegmatites where they are adjacent to carbonatites.

CONCLUSIONS

Carbonatites and related rocks intruded Upper Precambrian to Lower Paleozoic miogeoclinal host rocks prior to onset of the Columbian orogeny. There has apparently been more than one period of intrusive activity. Nepheline syenites at Mount Copeland are dated at 770 Ma (Okulitch, *et al.*, 1981) while other bodies are in the 350 to 250 Ma range (Ice River, Currie, 1975; Verity, White, personal communication).

None of the carbonatites in British Columbia are currently being mined. Although many have been tested as niobium and vermiculite prospects, information about their abundance, distribution, and economic potential are currently sketchy.

ACKNOWLEDGMENTS

I would like to thank Gordon White for guidance and sharing his knowledge of the carbonatites from Blue River area and Three Valley Gap. I also would like to thank Betty French and Scotty Almond for their advise on the Verity, Lonnie, and Vergil properties. Capable field assistance was provided by Gwenda Lorenzetti, hired by the Geological Branch of the Ministry of Energy, Mines and Petroleum Resources.

REFERENCES

Aaquist, B. (1982): Blue River Carbonatites, British Columbia, Final Report, 1981, Anschutz (Canada) Mining Ltd., *B.C. Ministry of Energy, Mines & Pet. Res.*, Assessment Report 10274, 289 pp.

Currie, K. L. (1975): The Geology and Petrology of the Ice River Alkaline Complex, *Geol. Surv., Canada*, Bull. 245, 65 pp.

.... (1976a): The Alkaline Rocks of Canada, *Geol. Surv., Canada*, Bull. 239, 228 pp.

.... (1976b): Notes on the Petrology of Nepheline Gneisses near Mount Copeland, British Columbia, *Geol. Surv., Canada*, Bull. 265, 31 pp.

Fyles, J. T. (1970): The Jordan River Area, near Revelstoke, British Columbia, *B.C. Ministry of Energy, Mines & Pet. Res.*, Bull. 57, 72 pp.

Halleran, A.A.D. (1980): Petrology, Mineralogy, and Origin of the Niobium-bearing Lonnie Carbonatite Complex of the Manson Creek Area, British Columbia, unpub. B.Sc. thesis, *Univ. of British Columbia*, 41 pp.

Hankinson, J. D. (1958): The Lonnie Group Columbian Deposit, unpub. B.Sc. thesis, *Univ. of British Columbia*, 32 pp.

Hoy, T. and Kwong, Y.T.J. (in preparation): The Mount Grace Carbonatite, A Pyroclastic Carbonatite Marble in the Shuswap Complex, Southeastern British Columbia.

McMillan, W. J. (1970): West Flank, Frenchman's Cap Gneiss Dome, Shuswap Terrane, British Columbia, *Geol. Assoc. Can.*, Special Paper 6, pp. 99-106.

.... (1973): Petrology and Structure of the West Flank, Frenchman's Cap Dome near Revelstoke, British Columbia, *Geol. Surv., Canada*, Paper 71-29.

McMillan, W. J. and Moore, J. M. Jr. (1974): Genissic Alkalic Rocks and Carbonatites in the Frenchman's Cap Gneiss Dome, Shuswap Complex, British Columbia, *Cdn. Jour. Earth Sci.*, Vol. 11, pp. 304-318.

Okulitch, A. V., Loveridge, W. D., and Sullivan, R. W. (1981): Preliminary Radiometric Analyses of Zircons from the Mount Copeland Syenite Gneiss, Shuswap Metamorphic Complex, British Columbia, *in* Current Research, Part A, *Geol. Surv., Canada*, Paper 81-1A, pp. 33-36.

Peterson, T. D. (1983): A Study of the Mineralogy and Petrology of the Ice River Complex, Yoho National Park, unpub. B.Sc. thesis, *Univ. of Calgary*, 133 pp.

Rowe, R. B. (1958): Niobium (Columbium) Deposits of Canada, *Geol. Surv., Canada*, Econ. Geol. Series 18, pp. 29-31.

FURTHER NOTES ON CARBONATITES IN CENTRAL BRITISH COLUMBIA (83D/6E, 7W)

By G.P.E. White

INTRODUCTION

Stratiform carbonatites, apparently with igneous strontium, carbon, and oxygen isotopes, and containing anomalous values of strontium and rare earths, occur from Revelstoke to north and east of Blue River (Fig. 25). Carbonatite crosscutting hosting schists is present on a small scale at Mount Copeland and south of Three Valley Gap. For the most part, however, these rocks are stratiform with fairly sharp to gradational, conformable contacts.

In the Blue River area there are a minimum of six carbonatite sites: Verity, Paradise Lake, Howard Creek, Gum Creek (with the Fir claims), Pyramid Creek, and Mud Lake. Several beds of carbonatite are usually found at each locality. The occurrences at Verity can be traced intermittently to Paradise Lake, 10 kilometres to the east. Carbonatite thicknesses of 30 metres have been recorded in drill sections from the Verity showing near Lempriere. Thinner but significant layers occur at most of the other Blue River sites.

Rocks that are referred to in this report as carbonatite contain anomalously high amounts of strontium and rare earths. They have variable mineralogical assemblages; the Mud Lake occurrence is typified by chondrodite, diopside, and garnet, while those at Verity, Paradise Lake, and Howard Creek have the mineralogy of marble, except for the presence of pyrochlore. Vertical mineral zoning is apparent in weathered outcrop at Mud Lake and Gum Creek, and in unweathered outcrop above timberline at Howard Creek. In unweathered outcrop, banding, possibly due to regional metamorphism, is in the form of concentrations of phlogopite or apatite; inexplicably, colour banding of 2 to 5-centimetre thickness, evident in weathered outcrops at Gum Creek, is not reflected in drill core.

Amphibolite to kyanite grade metamorphic rocks of the Shuswap Terrane host the carbonatites. At least three periods of structural deformation are evident at all the sites examined.

Attempts to correlate carbonatite bodies by pursuing daughter minerals in primary fluid inclusions in the ubiquitous accessory apatite, by studying the petrology of pyrochlore and other minerals, and by comparison of the quantity and type of rare earths present were not successful. Recent isotope studies by E. Ghent of the University of Calgary suggest that the carbonatites in the Verity area have an igneous origin (M. Mihalynuk, personal communication, 1984). Further studies are being carried out by

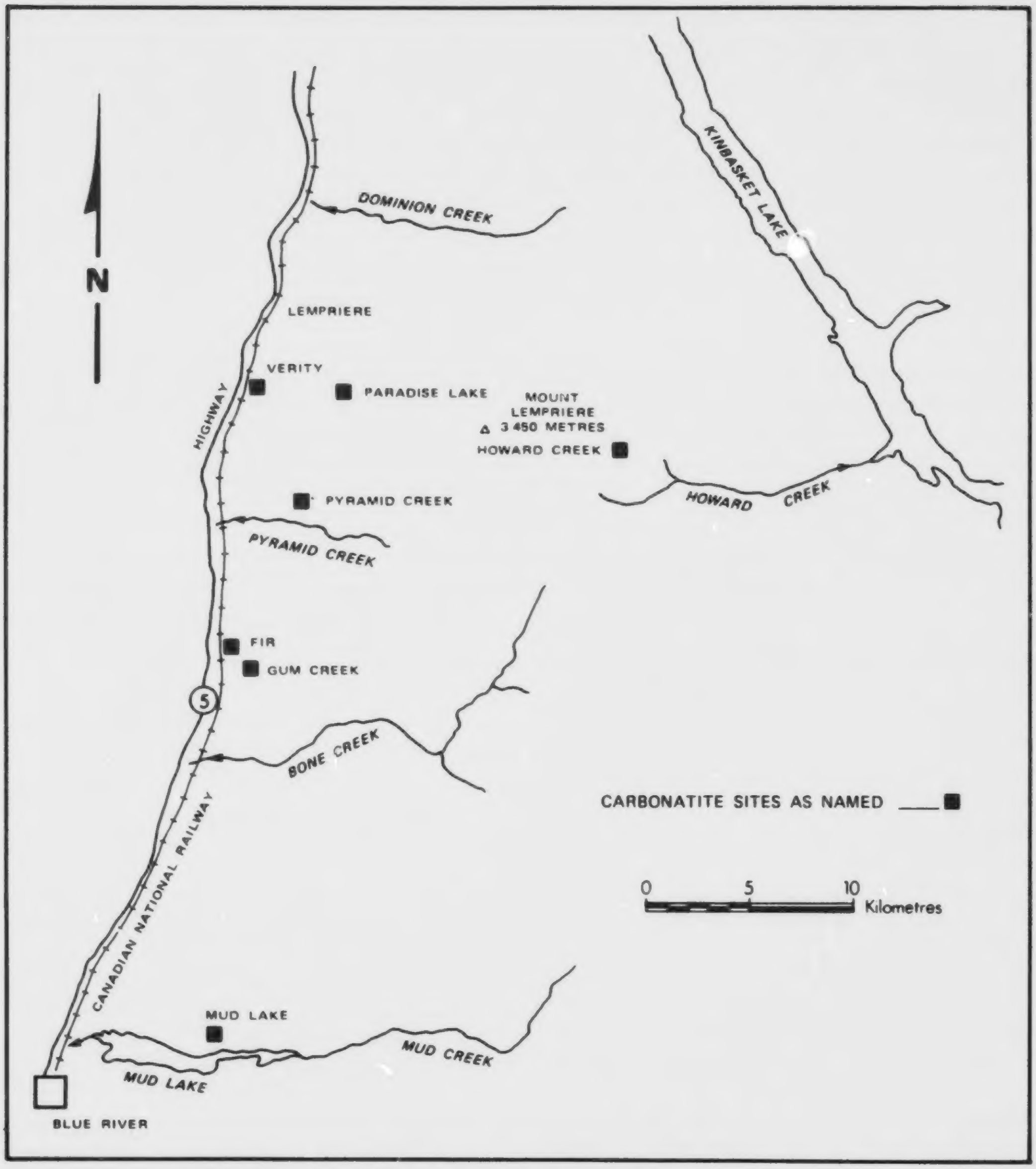

N
KINBASKET LAKE
DOMINION CREEK
LEMPRIERE
VERITY
PARADISE LAKE
MOUNT LEMPRIERE
Δ 3 450 METRES
HOWARD CREEK
HOWARD CREEK
HIGHWAY
PYRAMID CREEK
PYRAMID CREEK
FIR
GUM CREEK
5
BONE CREEK
CARBONATITE SITES AS NAMED ■
0
5
10
Kilometres
CANADIAN NATIONAL RAILWAY
MUD LAKE
MUD CREEK
MUD LAKE
BLUE RIVER

Figure 25. Blue River area. Map showing carbonatite localities.

J. Pell (*see* report, this volume) at the University of British Columbia; it is hoped that further studies of the strontium, oxygen, and carbon isotopes will answer some of the questions of origin. A study of correlative petrology is also required.

The volume, elemental content, and mineralogy of these carbonatites make them an important potential source of rare earths, niobium, phosphate, and vermiculite. The Verity and Gum Creek (Fir) carbonatites have been surveyed and drilled, while less extensive exploration has been carried out during the past two years in the Perry River (Revelstoke) area. Niobium was pursued at Verity while rare earths were sought at Perry River.

HOWARD CREEK (83D/7W)

The Howard Creek carbonatite occurrence is at the headwaters of Howard Creek, 13 kilometres west of [illegible]basket Lake and 41 kilometres northeast of Blue River at an elevation of 2 360 metres in an alpine setting. The carbonatites are hosted in a series of schists of amphibolite to kyanite metamorphic grade, which are part of the Shuswap Terrane. At least two separate bodies conformable to the regional schistosity and lithological layering have been identified within 300 metres of stratigraphic thickness. The structurally higher body contains nepheline syenite.

The regional foliation in the area trends east-west and dips 40 degrees south (Fig. 26). Cross-folding and right-hand *en echelon* faulting has displaced all rock units. As at other Blue River occurrences, this area has been subjected to at least three periods of structural deformation. In the earliest event, lithologic layering and the carbonatites were transposed parallel to the regional foliation. Drag folds and tight crenulations are evident in the carbonatites, particularly near their contact with the host rock.

At Howard Creek the carbonatite bodies vary in thickness from 10 centimetres to 20 metres. An interbed of schist less than 1 metre thick occurs within the carbonatite at the most western outcrop (Fig. 26). Most contacts of carbonatites with the schists are sharp but gradational contacts are present as well. Coarse banding of 5 to 50 centimetres is due to increased phlogopite content in the thinner bands. No crosscutting relations were noted.

Minerals identified in the Howard Creek carbonatites are calcite, dolomite, apatite, richterite, hornblende (possibly edenite), clinopyroxene (acmite-augite), sphene, biotite, phlogopite, nepheline (cancrinite), zircon, pyrochlore, baddeleyite, ilmenite, magnetite, pyrite, and plagioclase. The nepheline syenite body in the area of outcrop 35 (Fig. 26) is approximately 5 by 20 metres and appears to be concordant with the schist/carbonatite complex. Coarse-grained, biotite-rich bands up to 20 centimetres wide are in contact with the

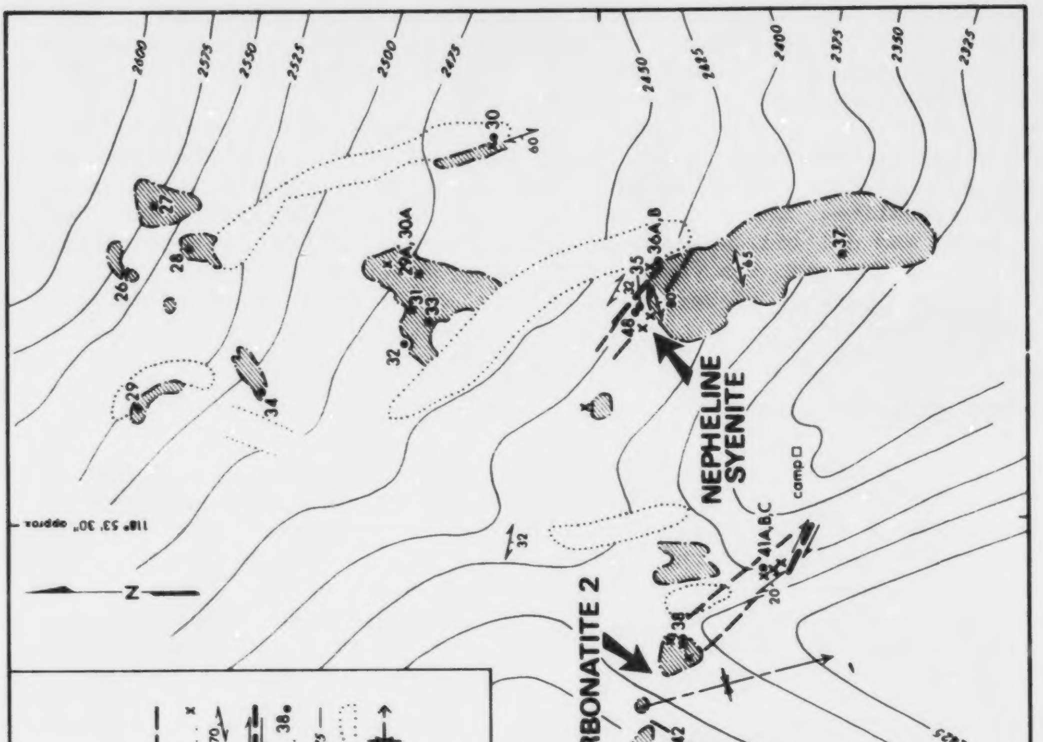

LEGEND
CARBONATITE
SCHIST
SYMBOLS
GEOLOGICAL CONTACT, ASSUMED
OUTCROP
ATTITUDE OF SCHISTOSITY
FAULT: APPARENT, ASSUMED, DIP INDICATED
SAMPLE NUMBER AND LOCATION
CONTOUR LINE, METRES ABOVE SEA LEVEL
SNOW
SYNFORM, PLUNGE DIRECTION INDICATED
SCALE - KILOMETRES
0
1
2
CARBONATITE 1
CARBONATITE 2
NEPHELINE SYENITE
camp
N
118° 53' 30" approx
52° 22' 50" approx
43A,B
41A,B,C
36A,B
29A,30A
2600
2575
2550
2525
2500
2475
2450
2425
2400
2375
2350
2325
2300
2275
2250
2225

Figure 26. Preliminary geological plan, Howard Creek carbonatite.

nepheline syenite. The nepheline syenite contains coarse-grained nepheline (40 per cent), hornblende (30 per cent), sphene (15 per cent), and biotite (15 per cent). The syenite minerals are relatively unaltered, suggesting possible recrystallization due to regional metamorphism. Infrequent boudins of coarse-grained amphibolite 5 to 50 centimetres long are found within the carbonatites and the nepheline syenite. The amphibolites are mainly hornblende, calcite, and sphene with lesser amounts of phlogopite.

Rock samples were collected from the carbonatite, the syenite, the adjacent schist, and from schist and amphibolite more than 1 kilometre away from the nearest carbonatite, and form a coarse-grained pegmatite approximately 3 kilometres to the northeast of the area mapped. These specimens were submitted for spectrographic analysis to determine whether content of strontium and rare earths varied from carbonatites to country rock, and, in particular, to see whether there was any similarity in the rare earth contents of the pegmatite and the carbonatites. Felsite and pegmatite are present away from the carbonatite but are of infrequent occurrence. A pegmatite body measuring 50 by 150 metres, that consists of quartz, albite, grey pearly muscovite, and secondary sericite, appears to crosscut a fine-grained garnetiferous, quartz-albite-hornblende schist.

Eighteen semi-quantitative analyses from the carbonatites and associated rocks, yielded 0.25 to 0.5 per cent strontium with an average content of 0.35 per cent; 0.20 per cent average strontium occurred in the carbonatite-hosted amphibolite; and 0.30 per cent average strontium in the adjacent schists. Strontium content of the amphibolite collected more than 1 kilometre away from the carbonatites registered only as trace. Strontium in the nepheline syenite is 0.07 per cent while that in the coarse-grained pegmatite is below detection limit.

Some elements from the carbonatites and their quantities as determined by spectrographic methods and expressed in per cent are: P >2.0, Sr 0.2, Ba 0.05, Zr 0.04, Cr 0.01, La 0.03, Ce 0.03, Nd 0.03; there are also trace amounts of Ga, Sn, Y, Yb, and Nb. The only significant difference in rare earth and trace element content, therefore, seems to be between the schists/carbonatite and the pegmatite. The mineralogy of the more distant amphibolite was similar to that of the amphibolites in the carbonatites, except for the presence of quartz.

The Verity carbonatite, 18 kilometres east of Howard Creek, is located 5 kilometres south of Lempriere, and 35 kilometres north of Blue River, approximately 100 metres above the North Thompson River on west-facing slopes. These carbonatites vary in composition from calcite to dolomite-rich and, with the exception of olivine, contain mostly the same minerals as those at Howard Creek. R. Parrish, while at the University of British Columbia, made two age determinations on zircons from the Verity site; both results are 325 Ma, indicating either a Chesterian age or deformation and recrystallization during Chesterian time.

CONCLUSIONS

A number of tentative conclusions may be drawn from the mineralogy and analyses. Due to their anomalously high strontium and rare earth contents, these rocks are probably true carbonatites despite their obvious stratigraphic conformity. High strontium in adjacent schists may indicate limited fenitization. The nepheline syenite may be a stock, or a centre of near surface igenous activity. The relatively distant pegmatite in the area does not appear to bear a genetic relationsip to the carbonatites.

As suggested, further work should be carried out on the comparative petrology of the carbonatites, as well as a study of the possible scavenger effects of rare earths by carbonatites during regional metamorphism.

ACKNOWLEDGMENTS

All analyses and mineral identities exclusive of thin section work were carried out at the British Columbia Ministry of Energy, Mines and Petroleum Resources' laboratory in Victoria. B. French of Blue River supplied some of the zircon crystals from Verity that were used for age dating. Dialogue was held in the field on several occasions with B. Aaquist, formerly of Anschutz Mining Corporation of Denver, Colorado, and Corporation geologists who visited the Howard Creek site on two occasions. Field assistance at Howard Creek was provided by S. Kennedy of Kamloops.

J & L
A STRATABOUND GOLD-ARSENIC DEPOSIT
SOUTHEASTERN BRITISH COLUMBIA
(82M/8)

By T. Höy

INTRODUCTION

The J & L prospect is a stratabound gold-silver-lead-zinc-arsenic deposit in a highly sheared quartzite-schist-limestone sequence, located 32 kilometres north of Revelstoke. It is 11 kilometres east from Highway 23 along a gravel road that follows the south side of Cairnes Creek. Surface exposures are restricted to a number of pits and trenches on a steep, heavily wooded slope at elevations of 820 to 1 220 metres between the north (McKinnon Creek) and south forks of Cairnes Creek.

The J & L was staked in 1896, and has undergone intensive but intermittent exploration and development work since. In 1924, Porcupine Goldfields Co. drove two 20-metre adits, and from 1941 to 1946 Raindor Gold Mines Ltd. sank two shallow shafts and extended the upper '3200-foot level' adit to 150 metres. Westair Mines Ltd. optioned the property from the present owner, T. E. Arnold, in 1965 and drove approximately 300 metres of drifts and crosscuts on the lower '2700-foot level.' The present operator, the Selco Division of B.P. Canada, Ltd., has done an extensive amount of rehabilitation work, extended the 2700-foot level to 830 metres, and drilled a number of underground holes from crosscuts on this level.

The purpose of this note is to overview the geology of the J & L deposit, based primarily on recent work by B.P.-Selco geologists, and to describe a section measured across the main mineralized zone.

GEOLOGY

J & L is within a highly deformed slice of Hadrynian and Paleozoic metasedimentary and metavolcanic rocks in the hangingwall of the Columbia River fault (*see* Fig. 28 of Gibson and Höy, this volume). Rocks in the Cairnes Creek area have been assigned to the Lower Paleozoic Lardeau Group (Wheeler, 1965), and host rocks to the J & L are the upper part of the Lower Cambrian Hamill Group (Grant, 1984). These include a number of cycles, 10 to 20 metres thick, that grade up from quartzite, through quartz-rich schist, to chlorite and sericite schist (R. Pegg, personal communication, 1984; Grant, 1984). A grey to carbonaceous limestone at the top of one of these cycles is immediately overlain by the main band of sulphides. Hangingwall rocks are highly sheared quartz-sericite and quartz-chlorite schists. These rocks, and the mineralized zones, trend northwest and dip northeast at about 55 degrees into the hill.

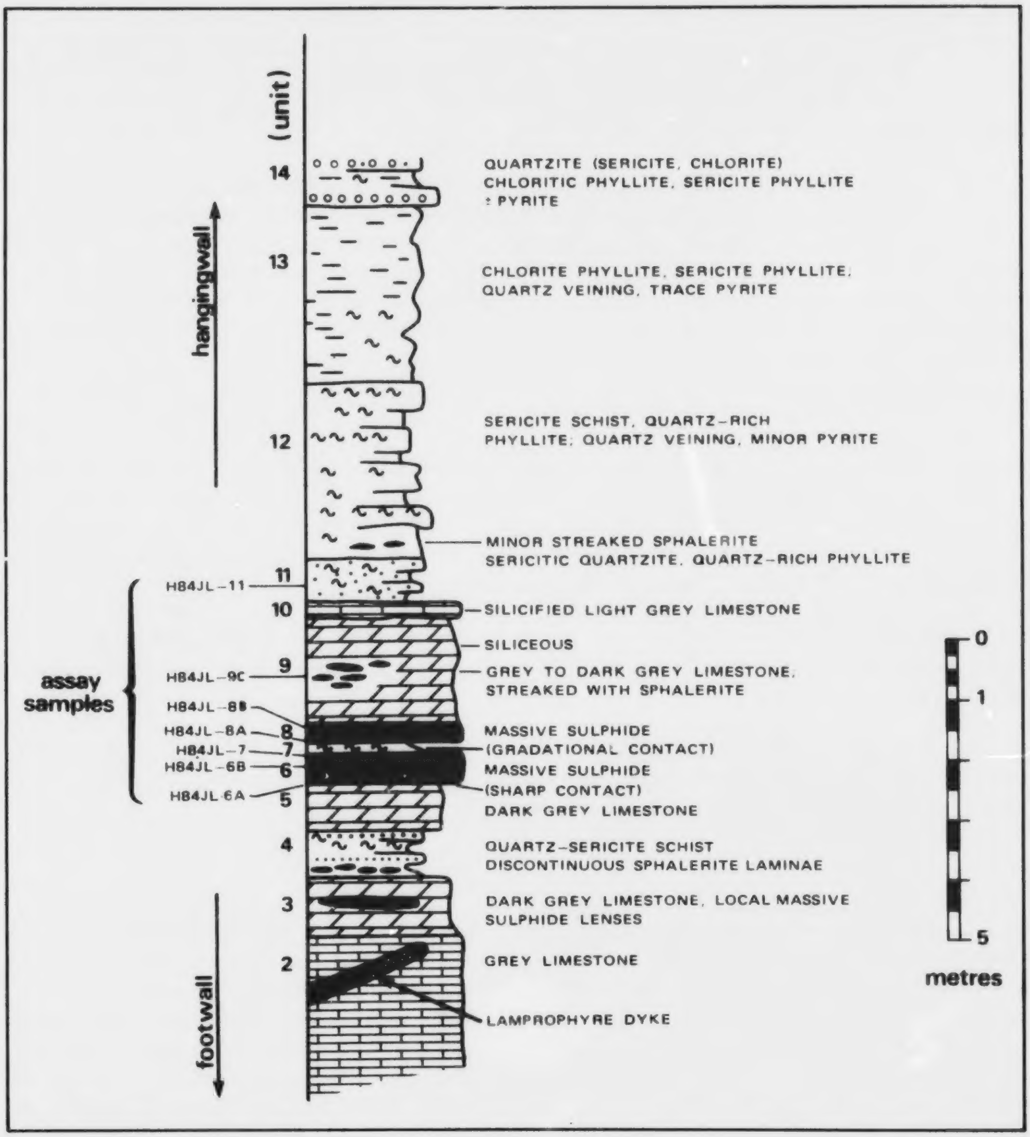

(unit)
14
QUARTZITE (SERICITE, CHLORITE)
CHLORITIC PHYLLITE, SERICITE PHYLLITE
± PYRITE
hangingwall
13
CHLORITE PHYLLITE, SERICITE PHYLLITE,
QUARTZ VEINING, TRACE PYRITE
12
SERICITE SCHIST, QUARTZ-RICH
PHYLLITE; QUARTZ VEINING, MINOR PYRITE
MINOR STREAKED SPHALERITE
SERICITIC QUARTZITE, QUARTZ-RICH PHYLLITE
11
H84JL-11
10
SILICIFIED LIGHT GREY LIMESTONE
SILICEOUS
9
H84JL-9C
GREY TO DARK GREY LIMESTONE,
STREAKED WITH SPHALERITE
assay
samples
H84JL-8B
H84JL-8A
8
MASSIVE SULPHIDE
H84JL-7
7
(GRADATIONAL CONTACT)
H84JL-6B
6
MASSIVE SULPHIDE
(SHARP CONTACT)
H84JL-6A
5
DARK GREY LIMESTONE
4
QUARTZ-SERICITE SCHIST
DISCONTINUOUS SPHALERITE LAMINAE
3
DARK GREY LIMESTONE, LOCAL MASSIVE
SULPHIDE LENSES
2
GREY LIMESTONE
LAMPROPHYRE DYKE
footwall
0
1
5
metres

Figure 27. J & L section, 10+350E crosscut.

The main mineralized band has been traced 1.9 kilometres along strike on surface and 830 metres underground. One underground zone is 190 metres in length and an average of 3 to 4 metres in width; it contains 4.5 grams gold per tonne, 49.5 grams silver per tonne, 1.43 per cent lead, 2.84 per cent zinc, and 3.5 per cent arsenic (Grant, 1984).

A number of other mineralized zones that occur on the property, such as the West zone, Far East, and North showings, may be extensions or fold repetitions of the main zone (Grant, 1984) or may be separate occurrences at a different stratigraphic level. Sulphides include pyrite, arsenopyrite, sphalerite, galena, and trace amounts of chalcopyrite and pyrrhotite; they are locally massive or occur as stringers, lenses, and disseminations in a quartz-sericite schist or a dark carbonaceous footwall limestone.

A detailed section through the main sulphide band in the 10+350-metre East crosscut is illustrated on Figure 27 and described in detail below. A thick, grey, well-banded limestone (unit 2) is overlain by a dark, impure carbonaceous limestone (unit 3) that locally contains discontinuous massive sulphide lenses. The overlying light grey quartz-sericite schist and sericitic quartzite (unit 4) have thin streaks and discontinuous laminations of reddish sphalerite, as well as disseminated grains of pyrite and arsenopyrite. The black, carbonaceous footwall limestone (unit 5), which is lithologically similar to unit 3, also contains minor amounts of disseminated sulphides and laminated sulphide lenses. The contact with the overlying massive sulphide layer (unit 6) is sharp. The sulphide layer consists of approximately 10 centimetres of laminated, reddish brown sphalerite, arsenopyrite, and coarse granular pyrite (unit 6A, Fig. 27; sample H84JL-6A, Table 1) that is overlain by 0.5 metre of more massive sphalerite and arsenopyrite (unit 6B). The sulphide content of unit 6 gradually decreases toward the top. Essentially massive sulphides (unit 6B) grade through sericite quartzite and quartz-sericite schist interlaminated with sulphides, to schist with only thin discontinuous streaks of sphalerite and arsenopyrite (unit 7). Unit 8 is a second massive sulphide layer approximately 0.5 metre thick. Coarse-grained arsenopyrite-sphalerite-pyrite occurs near the base (unit 8A, sample H84JL-8A) and finer grained sulphides near the top (sample H84JL-8B). Quartz 'eyes' and irregular quartz-sericite lenses are common throughout unit 8. A grey, laminated limestone (unit 9), approximately 2 metres thick, overlies the unit 8 massive sulphide layer in the 10+350 east crosscut. It is barren near the base, but darkens and becomes streaked with pink-coloured sphalerite near the middle (sample H84JL-9C); at the top it is a competent, light grey, silicified 'limestone' (unit 10). The calcareous interval is overlain by interlayered sericite schist, quartz phyllite, and quartzite of units 11 and 12. Irregular, discontinuous streaks and disseminations of pyrite, sphalerite, and lesser arsenopyrite are common throughout unit 11 and in the basal part of unit 12. Unit 13 includes chlorite phyllite with minor amounts of pyrite disseminated throughout; chloritic phyllite units begin appearing in unit 13.

TABLE 1
ASSAYS OF SELECTED HAND SAMPLES, J & L DEPOSIT, 10+350 METRE EAST CROSSCUT
(See Fig. 27 for sample localities)

Sample No.	Au ppm	Ag ppm	Cu per cent	Pb per cent	Zn per cent	As per cent	Sb per cent	Fe per cent
H84JL-6A	13	60	0.11	1.47	14.5	14.7	0.05	18.1
H84JL-6B	10	60	0.21	2.37	0.22	29.5	0.22	26.5
H84JL-7	<0.3	<10	0.02	0.03	0.02	0.24	<0.004	2.9
H84JL-8A	20.6	88	0.14	1.13	29.1	10.0	0.14	18.1
H84JL-8B	42.5	1 942	3.14	3.55	1.1	6.25	1.28	37.8
H84JL-9C	<0.3	<10	0.02	0.40	5.21	0.002	0.02	1.0
H84JL-11	<0.3	<10	0.04	0.06	0.01	0.015	<0.001	3.0

DISCUSSION

The J & L is an unusual 'massive' sulphide deposit. Intense regional deformation and associated regional metamorphism have obliterated virtually all primary structures, making conclusions regarding its origin subjective. Grant (1984) concluded that it is a 'sedex' or exhalitive sulphide deposit that accumulated syngenetically in a marine environment. Supporting evidence includes its form, a narrow thickness and great lateral extent, as well as locally its 'bedded' nature. Associated 'cherty' quartzites could also be of exhalitive origin and indicate a 'sedex' origin for the deposit. Earlier workers, however, interpreted the deposit to be a sheared replacement or vein deposit (Gunning, 1928; Wheeler, 1965). The mineralogy and its occurrence in an intensely sheared package of rocks supported this interpretation. However, arsenopyrite does occur in some exhalitive sedimentary deposits (for example, Sullivan) and in some volcanogenic deposits (for example, Bathurst camp deposits, New Brunswick). In conclusion, considerably more detailed petrography, structural studies, and perhaps isotopic analyses are needed to better understand and interpret the J & L deposit.

ACKNOWLEDGMENTS

I wish to acknowledge discussions with Selco Division geologists, Brian Grant and Brian Marten. Brian Grant is also thanked for his comments on this paper. The cooperation and discussions with property geologist, Rex Pegg, were particularly helpful.

REFERENCES

Grant, B. (1984): The J & L Deposit, *C.I.M.*, District 6 Meeting, Kamloops, Abstract, p. 23.

Gunning, H. C. (1928): Geology and Mineral Deposits of Big Bend Map-area, British Columbia, *Geol. Surv., Canada*, Prelim. Rept., pp. 136A-193A.

Wheeler, J. O. (1965): Geology of the Big Bend Map-area, British Columbia, *Geol. Surv., Canada*, Paper 64-32, 37 pp.

RIFT
A ZINC-LEAD MASSIVE SULPHIDE DEPOSIT IN SOUTHEASTERN BRITISH COLUMBIA
(82M/15)

By G. Gibson
Vancouver, British Columbia
and
T. Höy
Ministry of Energy, Mines and Petroleum Resources

INTRODUCTION

Rift is a stratiform zinc-lead-(copper-silver) massive sulphide showing located approximately 100 kilometres north of Revelstoke. It is easily accessible, exposed in a creek gully at an elevation of 750 metres, approximately 0.5 kilometre east, up the slope from Highway 23.

The Rift showing was discovered in 1980 as a result of a joint exploration program by J. M. Leask and E & B Exploration, Inc. Property mapping at 1:25 000 and 1:10 000 scales was initiated in 1981 by one of the authors (G. Gibson), and continued in 1982 (Gibson, 1981, 1982). Geophysical and geochemical surveys have been done in the immediate vicinity of the showing, but the continuation of the sulphide layer has not been tested by drilling. Detailed property mapping and a mineralogical study formed the basis of a B.Sc. thesis (Hicks, 1982).

REGIONAL TECTONIC SETTING

The Rift zinc-lead-(copper-silver) occurrence is in isoclinally deformed metasedimentary and metavolcanic rocks of the Selkirk allochthon in the immediate hangingwall of the east-dipping Columbia River fault zone (Fig. 28). The Selkirk allochthon is a composite terrane that was tectonically emplaced from west to east over core gneiss and mantling gneiss of the metamorphic infrastructure (Monashee Complex) along the Monashee decollement and Columbia River fault zone during Middle Mesozoic to Eocene time (Read and Brown, 1981).

Five kilometres north of the Rift occurrence the Columbia River fault terminates, and northwest-trending Hadrynian strata of the Horsethief Creek Group can be traced across Columbia Valley into the Shuswap Metamorphic Complex (Simony, *et al.*, 1980; Raeside and Simony, 1983). Major displacement along the fault in this area may be passed to at least three major southwest-dipping bedding faults or slides that splay eastward off the fault zone into the Selkirk allochthon. These three faults have been used to subdivide the northern Selkirk allochthon into tectonic slices (Read and Brown, 1981).

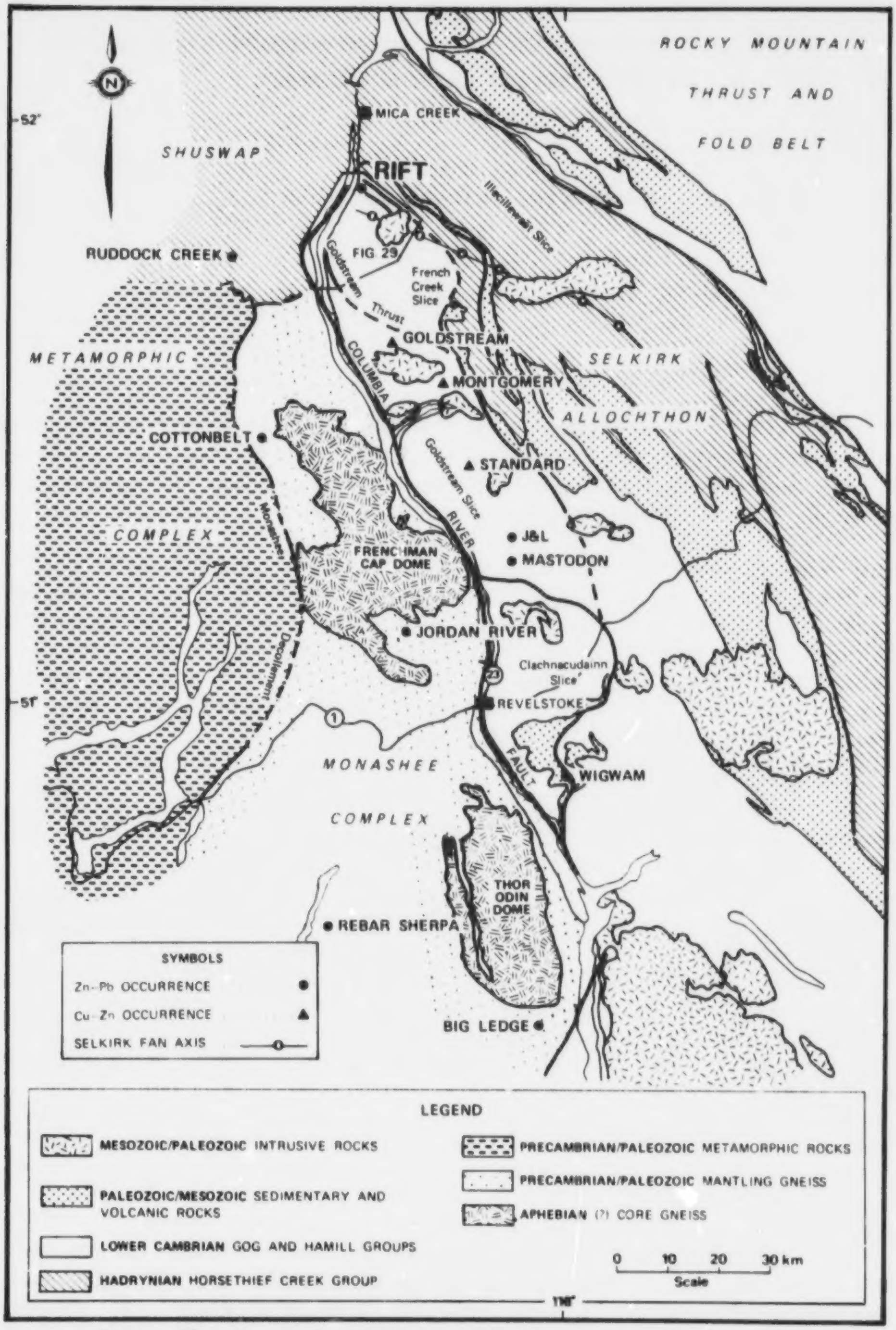

N
52°
51°
118°
SHUSWAP
METAMORPHIC
COMPLEX
MONASHEE
COMPLEX
ROCKY MOUNTAIN
THRUST AND
FOLD BELT
SELKIRK
ALLOCHTHON
RIFT
MICA CREEK
Illecillewaet Slice
FIG 29
French Creek Slice
Goldstream Thrust
GOLDSTREAM
MONTGOMERY
STANDARD
COLUMBIA
RIVER
Goldstream Slice
RUDDOCK CREEK
COTTONBELT
Monashee Decollement
FRENCHMAN CAP DOME
J&L
MASTODON
JORDAN RIVER
Clachnacudainn Slice
23
1
REVELSTOKE
FAULT
WIGWAM
THOR ODIN DOME
REBAR SHERPA
BIG LEDGE
SYMBOLS
Zn-Pb OCCURRENCE ●
Cu-Zn OCCURRENCE ▲
SELKIRK FAN AXIS
LEGEND
MESOZOIC/PALEOZOIC INTRUSIVE ROCKS
PALEOZOIC/MESOZOIC SEDIMENTARY AND VOLCANIC ROCKS
LOWER CAMBRIAN GOG AND HAMILL GROUPS
HADRYNIAN HORSETHIEF CREEK GROUP
PRECAMBRIAN/PALEOZOIC METAMORPHIC ROCKS
PRECAMBRIAN/PALEOZOIC MANTLING GNEISS
APHEBIAN (?) CORE GNEISS
0 10 20 30 km
Scale

Figure 28. Map of the Revelstoke-Mica Creek area showing major tectonic elements and base metal occurrences.

The French Creek, Goldstream, and Clachnacudainn slices (Fig. 28) contain overturned stratigraphy resulting from a period of early nappe formation (Phase 1) possibly initiated during the Devonian-Mississippian Cariboolan or Antler orogeny (Brown, 1978; Read and Brown, 1979). Subsequent polyphase folding, high-grade regional metamorphism, and granitic plutonism occurred during the Middle Jurassic Columbian orogeny.

Isoclinal Phase 2 folds are dominant along the southwestern flank of the Selkirk allochthon where they are strongly overturned toward the southwest (Lane, 1977; Höy, 1979). Phase 3 folds dominate on the northeastern flank where strata are overturned toward the northeast. An intervening zone of structural interference termed the Selkirk fan (Wheeler, 1965; Brown and Tippett, 1978) trends northwest, crossing from Illecillewaet slice into French Creek slice in the vicinity of Argonaut Mountain (Fig. 28).

STRUCTURE, METAMORPHISM, AND PLUTONIC ACTIVITY - BIGMOUTH CREEK AREA

South of Bigmouth Creek, structures are dominated by large recumbent isoclinal second phase folds with shallow northeast-plunging axes (Fig. 29). These folds comprise a structural stack at least 2 kilometres thick in the hangingwall of the Columbia River fault zone. A major structure of this generation is well exposed in the north canyon wall of Nicholls Creek where marble units are greatly thickened in the hinge of an east-closing synform. Marble units can be traced northward from Nicholls Creek along Route 23 to north of Bigmouth Creek where they gradually deflect eastward to resume the regional northwest structural grain. As they deflect, the attitudes of second phase isoclines change from northeastward with nearly flat-lying axial surfaces to northwestward with southwest-dipping axial surfaces and shallow southeast plunges.

Third phase folds are broad upright arches plunging northwest south of Bigmouth Creek but become compressed and isoclinal northward, where second and third phase structures are approximately coaxial. Superposition of coaxial second and third phase folds near the head of Beryl Creek produced megascopic Type 3 (Ramsay, 1967) interference patterns (Fig. 30).

Continuity of lithologies around the arcuate structural pattern north of Bigmouth Creek (Fig. 29) casts doubt on the existence, in the lower Bigmouth Creek area, of the 'Goldstream thrust' (Fig. 28), which is a north-dipping reverse fault separating French Creek slice from Goldstream slice (Campbell, 1972; Read and Brown, 1981). Instead, Goldstream thrust probably merges with the Columbia River fault in low ground near the mouth of Nicholls Creek, where elimination of stratigraphy has occurred along bedding faults that truncate the lower limb of Nicholls Creek synform (Fig. 28).

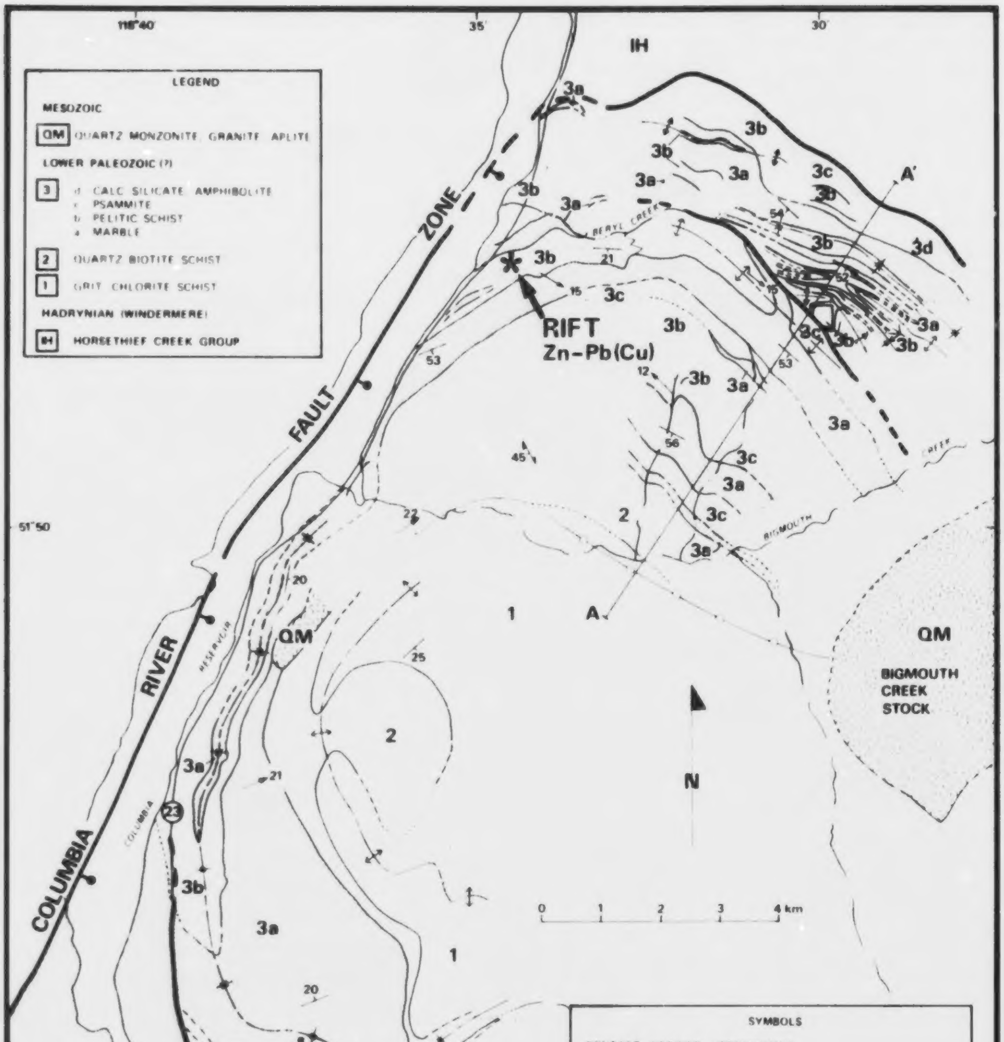

118°40'
35'
30'
IH
LEGEND
MESOZOIC
QM QUARTZ MONZONITE GRANITE APLITE
LOWER PALEOZOIC (?)
3 d CALC SILICATE AMPHIBOLITE
c PSAMMITE
b PELITIC SCHIST
a MARBLE
2 QUARTZ BIOTITE SCHIST
1 GRIT CHLORITE SCHIST
HADRYNIAN (WINDERMERE)
IH HORSETHIEF CREEK GROUP
COLUMBIA RIVER FAULT ZONE
RIFT
Zn-Pb(Cu)
BERYL CREEK
BIGMOUTH
A
A'
51°50'
QM
BIGMOUTH CREEK STOCK
N
RESERVOIR
COLUMBIA
23
NICHOLLS
0 1 2 3 4 km
SYMBOLS
CONTACT DEFINED APPROXIMATE ASSUMED
COLUMBIA RIVER FAULT ZONE DEFINED APPROXIMATE DOT ON HANGINGWALL (DOWNTHROWN) SIDE
FAULT DEFINED APPROXIMATE
SELKIRK FAN AXIS POSITION APPROXIMATE
ANTIFORM PHASE 2 PHASE 3
SYNFORM PHASE 2 PHASE 3
S_0 BEDDING PRIMARY LAYERING
S_2 FOLIATION SCHISTOSITY
F_2 FOLD AXIS
EDGE OF MAPPING OR OUTCROP
51°45'
40'
35'
118°30'

Figure 29. Map of the Bigmouth Creek-Nicholls creek area showing geological setting of the Rift zinc-lead(-copper) occurrence.

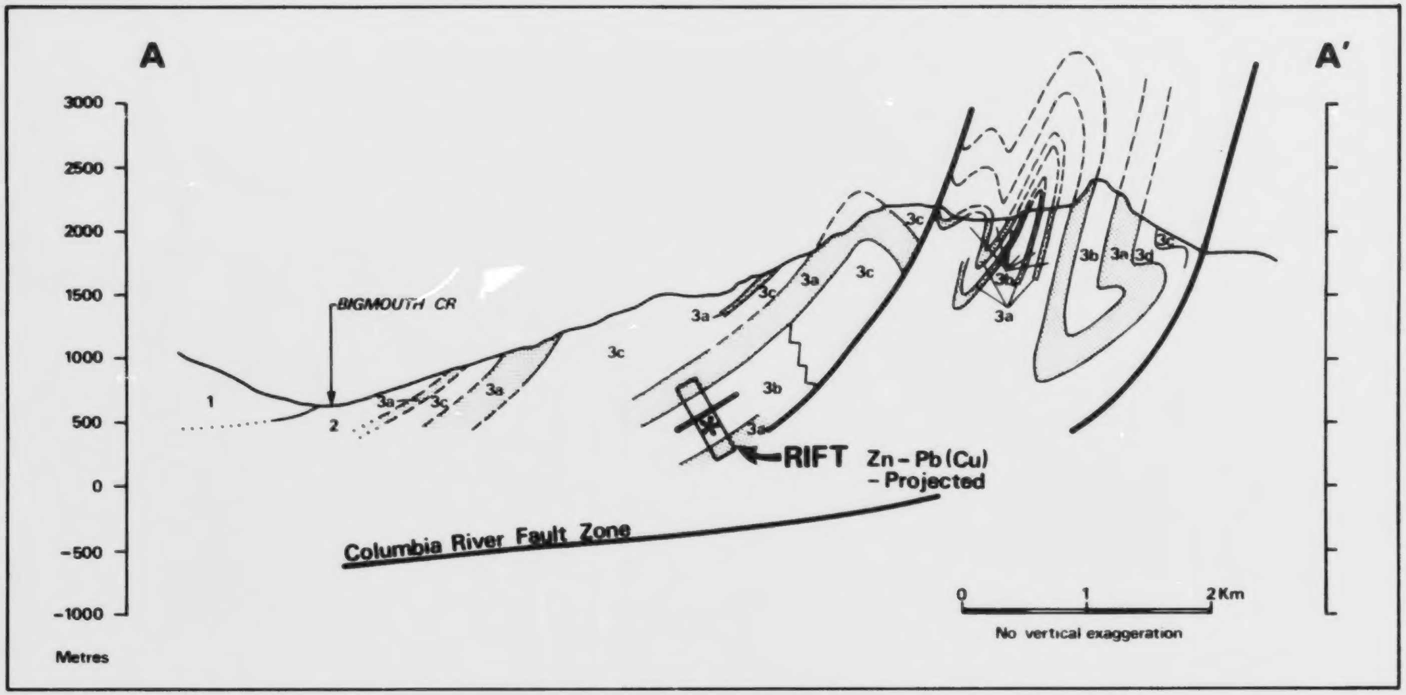

A
A′
3000
2500
2000
1500
1000
500
0
-500
-1000
Metres
BIGMOUTH CR
1
2
3a
3c
3b
3d
RIFT Zn-Pb(Cu)
-Projected
Columbia River Fault Zone
0
1
2Km
No vertical exaggeration

Figure 30. Structural cross-section. For location and legend see Figure 29. The box indicates the approximate stratigraphic interval exposed in Rift Creek and diagrammed onto the section.

At the outcrop scale, Phase 2 fabrics and fabrics associated with major stratigraphic inversion in Phase 1, are difficult to separate. The prevailing minor structure is a penetrative mineral foliation, outlined by mica grains in schistose rocks, that is axial planar to both Phase 1 and Phase 2 (designated S_2). Throughout the area mapped, S_2 and primary layering are parallel or near parallel, indicating isoclinal deformation. The limbs of associated minor folds (F_2) are severely attenuated along the S_2 foliation with complete transposition to rootless intrafolial isoclines common in many examples.

A steeply dipping crenulation cleavage (S_3) is axial planar to third phase minor folds; this cleavage is most apparent in the south where third phase axial surfaces are at a high angle to second phase foliation.

Grades of medium-pressure Barrovian metamorphism increase from south to north toward the 'Windy Range High' (Wheeler, 1965; Campbell, 1972; Leatherbarrow and Brown, 1978), a northwest-trending culmination in the sillimanite-K-feldspar metamorphic zone near Birch Creek. South of Bigmouth Creek, the widespread chlorite-biotite-muscovite-quartz assemblage in pelitic rocks defines a broad chlorite-biotite zone. This gives way northward to assemblages of the garnet zone and, in the vicinity of Rift Creek, to staurolite zone rocks. North of Beryl Creek, sillimanite-muscovite zone rocks are associated with pegmatite. Omission of kyanite zone rocks may be related to post-metamorphic faulting in Beryl Creek (Fig. 29).

Bigmouth Creek stock is a synkinematic (?) quartz monzonite pluton of probable Cretaceous age. Porphyry, with very large (to 5-centimetre) rimmed orthoclase phenocrysts embedded in a matrix of quartz, orthoclase, plagioclase, and biotite, is cut by late stage leucocratic granite and aplite.

LITHOLOGY

Detailed mapping in 1981 and 1982 has confirmed the lateral equivalence of marble units in Nicholls canyon (Lower Cambrian Badshot Formation of Wheeler, 1965) with marbles north of Bigmouth Creek (Hadrynian Horsethief Creek Group of Wheeler, 1965 and Brown, *et al.*, 1977). This gives rise to regional stratigraphic and structural problems that cannot be resolved without further mapping between Nicholls Creek and the Goldstream copper-zinc deposit (Fig. 28). At present, formal assignment of map units to the Paleozoic Hamill Group (Marsh Adams Formation, Mohican Formation) and Lardeau Group (Badshot Formation, Index Formation, Jowett Formation, Broadview Formation) on the one hand, or the Hadrynian Horsethief Creek Group on the other, is not possible.

Three informal lithologic sequences were distinguished in the Nicholls Creek area: an eastern grit sequence (unit 1), a central 'pelite' sequence (unit 2), and a western carbonate sequence (unit 3). Top determinations from graded grit beds in unit 1 indicate that stratigraphy becomes younger toward the core of Nicholls Creek synform; this provides the basis for Figure 31a, a composite stratigraphic section. Note that scale bars on Figure 31 are approximate in view of the pronounced tectonic thickening of units in fold hinges and thinning on limbs.

UNIT 1 - 900 metres (base not exposed)

This unit consists of massive graded grit and laminated chlorite schist cycles in rhythmic units 10 to 50 metres thick. Narrow impure marble layers and talc schist lenses are a minor component of the section, as are massive, dark grey hornblende-garnet calc-silicate layers to 10 metres in thickness. The upper contact of unit 1 is locally marked by a clean calcite marble layer up to 5 metres thick.

UNIT 2 - 200 metres

In unit 2, dark, recessive, locally graphitic quartz-biotite schist predominates. Banding, on a 1 to 10-centimetre scale, is caused by alignment of lensoidal quartz segregations that contain carbonaceous or micaceous layers and limy partings. Pyrrhotite comprises up to 10 per cent of the rock as fine disseminations and streaks, leading to rusty-weathering colours in most outcrops. The upper contact of unit 2 is transitional with unit 3 where interlayers of friable calcareous schist or impure marble appear in the section.

UNIT 3 - 500 metres (top not exposed)

South of Bigmouth Creek, unit 3 includes two prominent massive, grey, thick-bedded marble units, each 150 to 200 metres thick, separated by 200 to 400 metres of schist. Marble units are mainly calcitic, but are locally dolomitized or silicified. Layering is enhanced by variations in calcite grain size and by intercalations of argillaceous or micaceous material. Upper and lower contacts of the carbonate rock units are usually poorly defined and comprise zones of pure and impure marbles alternating with schists and other clastic rocks.

Schists of unit 3 are rusty weathering, banded, and variably graphitic or calcareous. Dark greenish black 'greasy'-lustered chloritic layers mimic graphite in some exposures; with increasing chlorite content the rock grades to thick-layered quartz-chlorite schist with chert layers and lenses. Pink garnets and pyrite-pyrrhotite disseminations are common and black manganese crusts develop on fractures cutting the unit.

Several horizons of white-weathering orthoquartzite, that are 10 to 30 metres thick, are a minor but distinctive component of unit 3 south of Bigmouth Creek.

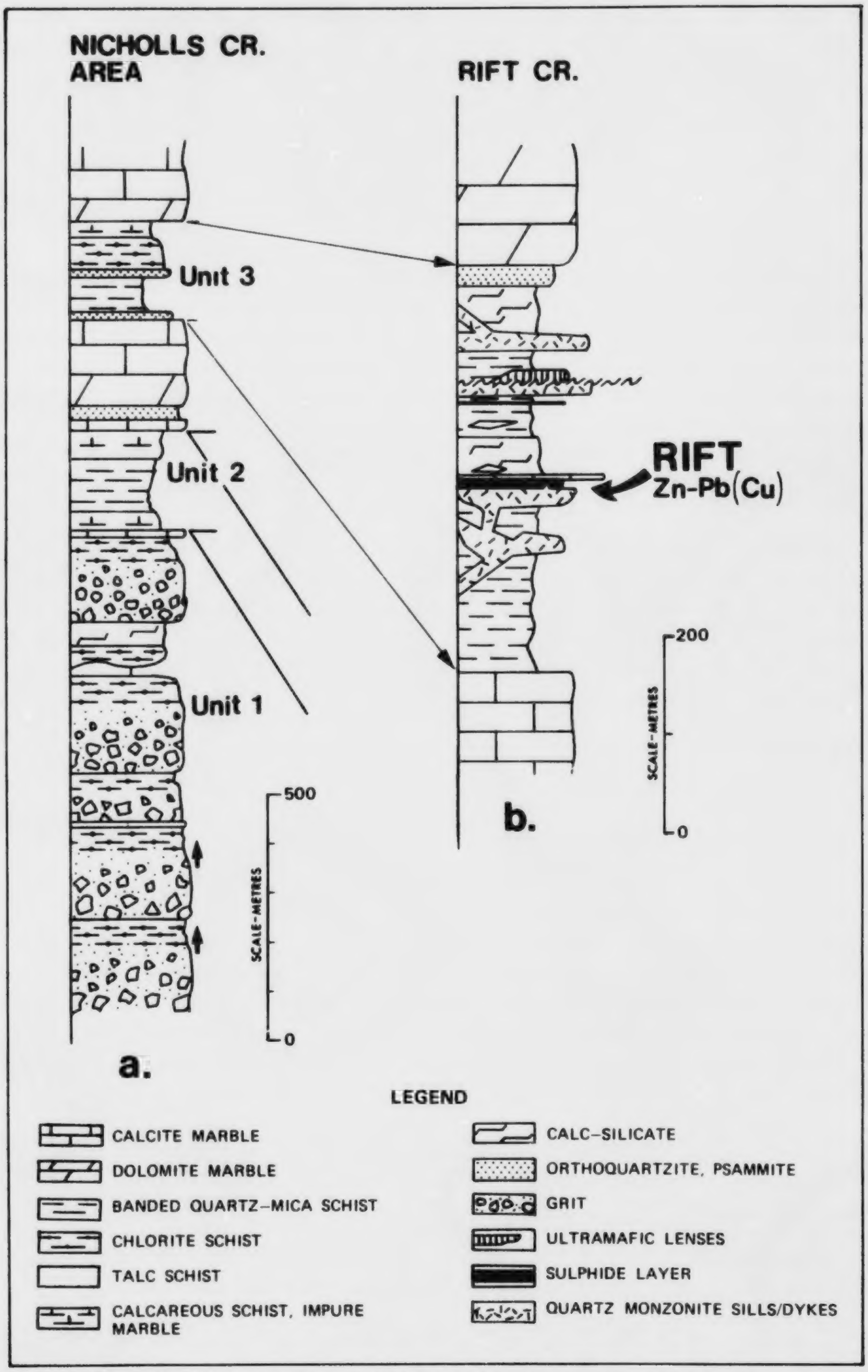

NICHOLLS CR.
AREA
RIFT CR.
Unit 3
Unit 2
Unit 1
RIFT
Zn-Pb(Cu)
500
SCALE-METRES
0
a.
200
SCALE-METRES
0
b.
LEGEND
CALCITE MARBLE
DOLOMITE MARBLE
BANDED QUARTZ-MICA SCHIST
CHLORITE SCHIST
TALC SCHIST
CALCAREOUS SCHIST, IMPURE MARBLE
CALC-SILICATE
ORTHOQUARTZITE, PSAMMITE
GRIT
ULTRAMAFIC LENSES
SULPHIDE LAYER
QUARTZ MONZONITE SILLS/DYKES

Figure 31. Stratigraphy of the Nicholls Creek area and Rift Creek showing lithologic setting of Rift zinc-lead(-copper) occurrence.

North of Bigmouth Creek the Rift zinc-lead-(copper-silver) sulphide layer is contained in a 400-metre-thick, varied but largely schistose interval of unit 3 that lies between marble units (Fig. 31b). Staurolite zone rocks exposed in Rift Creek consist of layered quartz-garnet pelitic schists and layered calc-silicate rocks with subordinate psammite and marble. Intrusive masses of K-feldspar porphyritic garnet-biotite quartz monzonite invade the metasedimentary rocks as sills, dykes, and narrow (<10-centimetre) anastomosing, layer-parallel tongues; contacts are often gradational against the country rocks. One hundred metres above the sulphide layer is a pod-like, sheared ultramafic body, 15 metres thick, containing large (to 3-centimetre) cleaved metacrysts of magnesite in a matrix of antigorite, talc, and magnetite. The ultramafic body contains 2 300 ppm nickel, 106 ppm cobalt, and 175 ppm copper (Hicks, 1982).

North of Beryl Creek polydeformed strata of unit 3 are in the sillimanite metamorphic zone. These include at least three coarsely recrystallized calcite marble layers, 10 to 100 metres thick, separated by quartz-mica schist, psammite, amphibolite, and calc-silicate rock (Fig. 30).

RIFT ZINC-LEAD-(COPPER-SILVER) DEPOSIT

The Rift showing consists of a number of thin layers of massive sphalerite, pyrite, pyrrhotite, and galena exposed for approximately 25 metres of strike length in a steep-sided creek gully; the thickest of the layers is about 2 metres thick. A number of thin discontinuous massive sulphide lenses, separated by schistose quartz-rich and somewhat calcareous rocks with disseminated sulphides, occur in the immediate 2 to 3 metres of footwall (Fig. 32). Hangingwall rocks are more calcareous and sulphide content is generally lower. A second massive sulphide zone, called the 'upper showing' (Hicks, 1982), is exposed approximately 90 metres stratigraphically above the main showing. Intervening rocks include calcareous schists and thin marble bands, overlain by more pelitic schists.

The massive sulphide layers are irregularly laminated on a <1 to 10-centimetre scale. Individual laminae consist of granular, sphalerite-rich assemblages; fine-grained, dark sphalerite; fine-grained galena that contains 1 to 2-millimetre rounded pyrite clots; or medium-grained pyrite or pyrrhotite-rich layers. Sphalerite is commonly the most abundant sulphide; pyrrhotite is abundant in the southern part of the creek gully exposure, whereas pyrite predominates in the northern part (Hicks, 1982). Galena averages from 5 to 8 per cent, and chalcopyrite and arsenopyrite occur in trace amounts. Predominant gangue minerals in the massive sulphide layers include quartz, muscovite, calcite, and minor amounts of clinozoisite. Thin calc-silicate and quartz-rich gangue layers with variable amounts of disseminated sulphides occur within the sulphide layers.

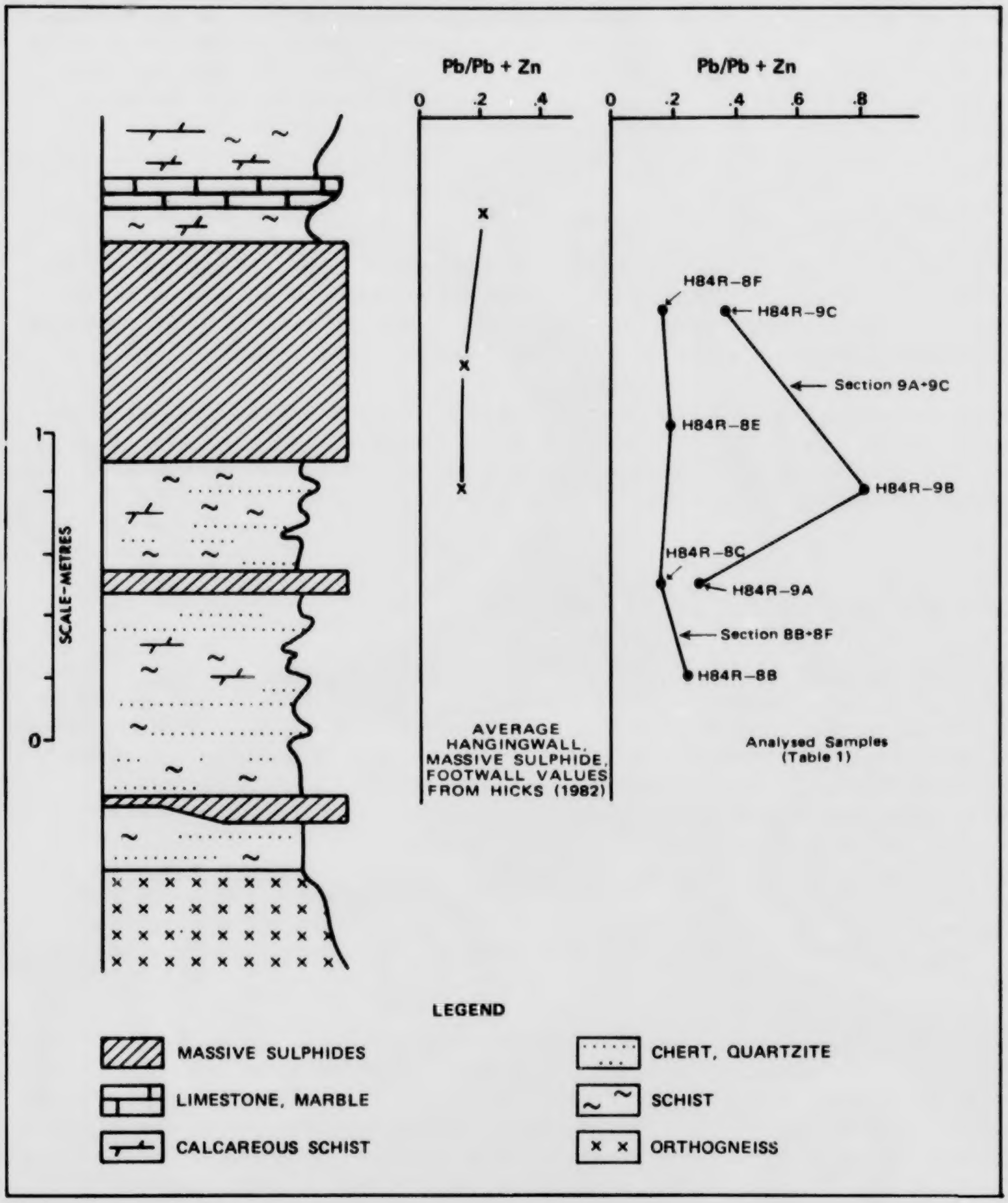

Pb/Pb + Zn
0
.2
.4
Pb/Pb + Zn
0
.2
.4
.6
.8
1
SCALE-METRES
0
H84R-8F
H84R-9C
Section 9A-9C
H84R-8E
H84R-9B
H84R-8C
H84R-9A
Section 8B-8F
H84R-8B
AVERAGE HANGINGWALL, MASSIVE SULPHIDE, FOOTWALL VALUES FROM HICKS (1982)
Analysed Samples (Table 1)
LEGEND
MASSIVE SULPHIDES
LIMESTONE, MARBLE
CALCAREOUS SCHIST
CHERT, QUARTZITE
SCHIST
ORTHOGNEISS

Figure 32. Detailed section through Rift massive sulphide lenses showing sample locations (Table 1) and Pb/Pb + Zn ratios.

Chemical analyses of the massive sulphide layers reflect the high sphalerite content, with zinc ranging from approximately 24 to 32 per cent (Table 1). The weighted average of 25 chip samples is 29.75 per cent zinc, 5.28 per cent lead, and 0.03 per cent copper (Hicks, 1982). Gold values ranged from 0.06 to 0.25 gram per tonne and silver, from 0.3 to 10 grams per tonne in seven grab samples collected by J. M. Leask (personal communication, 1980). Gold and silver values for the six massive sulphide samples analysed in this study (Table 1) were below the utilized detection limits of 0.3 and 10 grams per tonne respectively. Semi-quantitative emission spec values for barium ranged from trace amounts to 1.2 per cent in a footwall sample (84R-9B). Hicks (1982) reported a slight but distinct chemical zonation with Pb/Pb + Zn increasing vertically. This was not confirmed, however, in our limited sampling; in two sets of chip samples across the sulphide layers and immediate host rocks Pb/Pb + Zn apparently varied randomly from approximately 0.18 to 0.8 (Table 1; Fig. 32).

TABLE 1
BASE METAL ANALYSES OF MASSIVE SULPHIDE LENSES AND HOST ROCKS, RIFT SHOWING
(See Fig. 32 for sample locations)

No.	Pb per cent	Zn per cent	Cu per cent	Pb/Pb+Zn	Lithology
84R-10	5.75	29.3	0.017	0.164	upper massive sulphide lens
84R-9C	13.9	25.1	0.009	0.356	main massive sulphide lens
84R-8F	6.83	31.7	0.067	0.177	main massive sulphide lens
84R-8E	7.01	31.3	0.067	0.182	main massive sulphide lens
84R-9B	0.048	0.012	0.018	0.800	siliceous, calcareous schist
84R-9A	9.01	23.9	0.039	0.273	lower massive sulphide lens
84R-8C	5.00	26.8	0.032	0.157	lower massive sulphide lens
84R-8B	0.015	0.074	0.021	0.202	chert, quartzite, siliceous schist

Disseminated sulphides, primarly pyrrhotite and sphalerite, occur throughout the immediate footwall rocks; zinc averages 3.11 per cent and lead, 0.48 per cent (Hicks, 1982). Sulphide content in hangingwall rocks is lower; zinc averages 0.8 per cent and lead, 0.2 per cent.

Immediate host rocks for the massive sulphide layer include calcareous, quartz-rich schists. They strike east-southeast and dip variably to the south (Fig. 33). Tight to isoclinal minor folds and a distinct biotite and muscovite foliation that generally parallels layering reflect the intense regional deformation. Thin, rusty weathering amphibolite, calc-silicate gneiss, and diopside and actinolite-bearing marble layers occur in both footwall and hangingwall rocks. Dark grey, fine-grained impure quartzite layers are common in the footwall, and an impure marble forms the immediate hangingwall. Medium to coarse-grained orthogneiss, and late stage quartz monzonite sills and dykes intrude the succession.

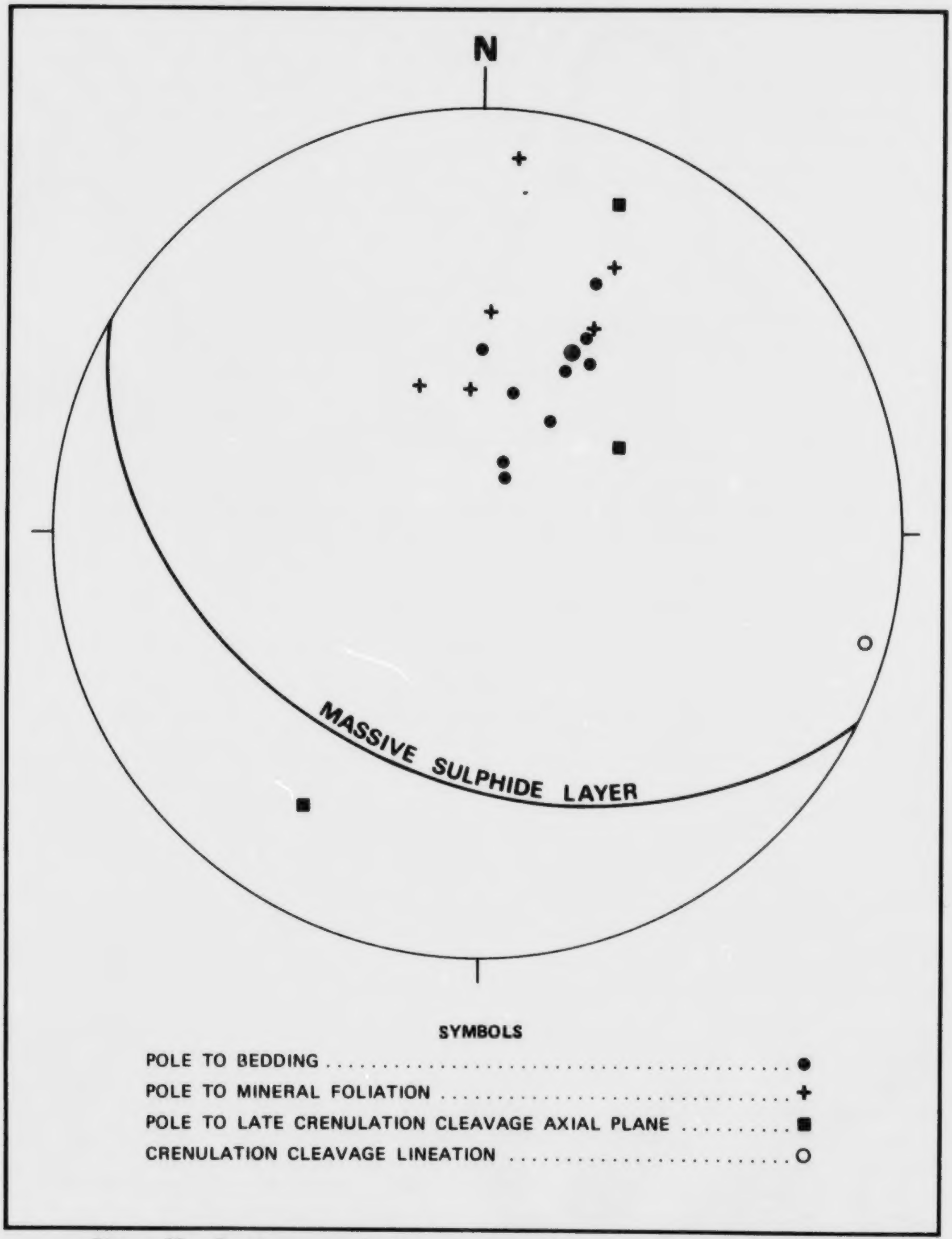

N
MASSIVE SULPHIDE LAYER
SYMBOLS
POLE TO BEDDING ●
POLE TO MINERAL FOLIATION +
POLE TO LATE CRENULATION CLEAVAGE AXIAL PLANE ■
CRENULATION CLEAVAGE LINEATION ○

Figure 33. Equal area projection of structural elements in the vicinity of the Rift showing.

COMPARISON WITH OTHER LEAD-ZINC DEPOSITS, SOUTHEASTERN BRITISH COLUMBIA

The Rift deposit contrasts markedly with lead-zinc deposits in the Kootenay Arc to the south (Fyles, 1970; Höy, 1982). Kootenay Arc deposits include deposits in the Salmo camp, and the Bluebell, Duncan, and Wigwam deposits (Fig. 28). They are hosted by a relatively pure, but locally dolomitized, silicified, and brecciated Lower Cambrian carbonate unit. Although deformation may be intense, the regional metamorphism is generally of greenschist facies grade. Rift has, however, many similarities with lead-zinc deposits that occur in the Shuswap Metamorphic Complex to the west. These deposits include Cottonbelt and Jordan River on the flanks of Frenchman Cap dome and Big Ledge on the southern flank of Thor Odin dome (Fig. 28). These deposits are large, stratabound, sulphide-rich layers within well-layered platformal successions of dominantly carbonate, schist, and quartzite (Hoy, 1982). The immediate host rocks are generally calcareous schists. Pyrrhotite and sphalerite are the dominant sulphides, with galena and pyrite as minor phases. Shuswap deposits, and the Rift deposit, are part of the enclosing stratigraphic succession and have undergone all phases of the intense regional metamorphism and deformation. They are examples of the 'exhalitive sedimentary' (or sedex) deposits of Hutchinson (1980), and formed by base metal accumulations in a shallow marine, dominantly clastic environment.

Age estimates for the Rift showing from galena-lead isotope data (C. I. Godwin, personal communication, 1984) summarized in Hicks (1982) are Lower Cambrian to Upper Hadrynian (approximately 0.52 Ga). Similar isotopic characteristics and age estimates are obtained for the stratiform deposits of the Anvil district, Yukon Territory and the Cottonbelt deposit (Hicks, 1982).

ACKNOWLEDGMENTS

The unpublished thesis by Hicks (1982), the regional work by G. Gibson, and two brief visits to the property by T. Höy, followed by petrographic studies and work by the analytical laboratory of the Ministry of Energy, Mines and Petroleum Resources, form the basis of this report. The authors wish to thank the owners, Beaumont Timber Co. Ltd. and Mascot Gold Mines, Ltd. (formerly E & B Exploration, Inc.), for permission to publish this paper; Ken Hicks for his capable assistance in all phases of the property assessment; and R. L. Brown, L. Lane, W. J. McMillan, M. Perkins, P. S. Simony, and J. O. Wheeler for informative and stimulating discussions.

REFERENCES

Brown, R. L. (1978): Structural Evolution of the Southeast Canadian Cordillera: A New Hypothesis, *Tectonophysics*, Vol. 48, pp. 133-151.

Brown, R. L., Perkins, M. J., and Tippett, C. R. (1977): Structure and Stratigraphy of the Big Bend Area, British Columbia, *in* Report of Activities, Part A, *Geol. Surv., Canada,* Paper 77-1A, pp. 273-275.

Brown, R. L. and Tippett, C. R. (1978): The Selkirk Fan Structure of the Southeastern Canadian Cordillera, *Geol. Soc. Am.,* Bull., Vol. 89, pp. 548-558.

Campbell, R. B. (1972): Geological Map of Part of the Southeastern Canadian Cordillera, *in* Structural Style of the Southern Canadian Cordillera, *XXIV Int. Geol. Congress,* Field Excursion X01-A01, Fig. 2.

Fyles, J. T. (1970): Geological Setting of Pb-Zn Deposits in the Kootenay Lake and Salmo Areas, British Columbia, *in* Lead-zinc Deposits in the Kootenay Arc, Northeast Washington and Adjacent British Columbia, *Dept. of Nat. Res.,* State of Washington, Bull. 61, pp. 41-53.

Gibson, G. (1981): Geological and Geochemical Report, Rift, Rift 2, Omega, Mica 5-18, and Mica 19 Fr. Mineral Claims, *B.C. Ministry of Energy, Mines & Pet. Res.,* Assessment Report 9638, 23 pp.

.... (1982): Geological and Geochemical Report, Mica 20-36 Mineral Claims, *B.C. Ministry of Energy, Mines & Pet. Res.,* Assessment Report 10989, 28 pp.

Hicks, K. E. (1982): Geology and Mineralogy of the 'Rift' Zinc-lead Massive Sulfide Deposit, Southeastern British Columbia, unpub. B.Sc. thesis, *Univ. of British Columbia,* 55 pp.

Höy, T. (1979): Geology of the Goldstream Area, *B.C. Ministry of Energy, Mines & Pet. Res.,* Bull. 71, 49 pp.

.... (1982): Stratigraphic and Structural Setting of Stratabound Lead-zinc Deposits, Southeastern British Columbia, *C.I.M.,* Bull., Vol. 75, No. 840, pp. 114-134.

Höy, T. and Brown, R. L. (1981): Geology of the Eastern Margin of the Shuswap Complex, Frenchman Cap Area, *B.C. Ministry of Energy, Mines & Pet. Res.,* Prelim. Map 43.

Höy, T., Gibson, G., and Berg, N. W. (1984): Copper-zinc Deposits Associated with Basic Volcanism, Goldstream Area, Southeastern British Columbia, *Econ. Geol.,* Vol. 79, pp. 789-814.

Hutchinson, R. W. (1980): Massive Base Metal Sulphide Deposits as Guides to Tectonic Evolution, *in* The Continental Crust and its Mineral Deposits, D. F. Strangway, editor, *Geol. Assoc. Can.,* Special Paper 20, pp. 659-684.

Lane, L. H. (1977): Structure and Stratigraphy, Goldstream River-Downie Creek Area, Selkirk Mountains, British Columbia, unpub. M.Sc. thesis, *Carleton Univ.,* 140 pp.

Leatherbarrow, R. R. and Brown, R. L. (1978): Metamorphism of the Northern Selkirk Mountains, British Columbia, *in* Current Research, Part A, *Geol. Surv., Canada,* Paper 78-1A, pp. 81, 82.

Raeside, R. P. and Simony, P. S. (1983): Stratigraphy and Deformational History of the Scrip Nappe, Monashee Mountains, British Columbia, *Cdn. Jour. Earth Sci.*, Vol. 20, pp. 639-650.

Ramsay, J. G. (1967): Folding and Fracturing of Rocks, *McGraw-Hill*, New York, 568 pp.

Read, P. B. and Brown, R. L. (1979): Inverted Stratigraphy and Structures, Downie Creek, Southern British Columbia, *in* Current Research, Part A, *Geol. Surv., Canada*, Paper 79-1A, pp. 33, 34.

Read, P. B. and Brown, R. L. (1981): Columbia River Fault Zone: Southeastern Margin of the Shuswap and Monashee Complexes, Southern British Columbia, *Cdn. Jour. Earth Sci.*, Vol. 18, pp. 1127-1145.

Simony, P. S., Ghent, E. D., Craw, D., Mitchell, W., and Robbins, D. B. (1980): Structural and Metamorphic Evolution of Northeast Flank of Shuswap Complex, Southern Canoe River Area, British Columbia, *Geol. Soc. Am.*, Mem. 153, pp. 445-461.

Wheeler, J. O. (1965): Big Bend Map-area, British Columbia, *Geol. Surv., Canada*, Paper 64-32.

HARRISON LAKE PROJECT

(92H/5, 12; 92G/9, 16)

By G. E. Ray
Ministry of Energy, Mines and Petroleum Resources
and
S. Coombes
Rhyolite Resources Inc.

INTRODUCTION

Six days were spent in the Harrison Lake area during the summer of 1984. This fieldwork included geochemical sampling of various rock suites in the vicinity of Doctors Point and geological mapping a stratigraphic section in the Fire Mountain area. The latter work also involved examining and sampling the Money Spinner (Mineral Inventory 92G/NE-2) and the Blue Lead (Mineral Inventory 92G/NE-4) gold-bearing veins which form part of the Fire Lake gold camp. This report concerns ongoing research into the geology, geochronology, and gold mineralization of the Harrison Lake fracture system; previous recent work on the regional mineralization is outlined by Ray, *et al.* (1984).

RN MINE (GEO) (Mineral Inventory 92H/SW-92)

The defunct RN gold mine, situated approximately 4 kilometres northeast of Harrison Hot Springs, lies within a biotite-hornblende diorite close to its intrusive margin with Chilliwack Group metapelites. The gold is hosted in thin, massive quartz veins that carry disseminations and clots of pyrrhotite, pyrite, and sericite with traces of chalcopyrite and molybdenite (Ray, *et al.*, 1984). Some veins also contain traces of scheelite and bismuth telluride (D. MacQuarrie, personal communication, 1984). The sericite in these veins gives a K/Ar age of 24.5±1 Ma (J. Harakal, personal communication, 1984; Table 1); this is the apparent age of the gold mineralization. Biotite and hornblende concentrated from samples of the diorite pluton host are currently being dated by K/Ar methods.

TABLE 1
K/Ar AGE DATE, RN MINE, HARRISON LAKE*

Field No.	Location	Rock Type	Material Analysed	Age (Ma)
RR 55	Adit entrance of defunt RN mine, 4.5 kilometres northeast of Harrison Hot Springs (49°20'10"N, 122°45'01"W)	Quartz vein with sericite, pyrrhotite, and pyrite	Sericite (-40+80)	24.5±1.0

*Collected by G. E. Ray (1983)

DOCTORS POINT

The simplified geology of the Doctors Point area, situated approximately 45 kilometres northwest of Harrison Hot Springs, is shown on Figure 34. A suite of moderately dipping volcanic, volcaniclastic, and sedimentary rocks are intruded by five bodies of diorite to quartz diorite composition that range from less than 50 metres to over 2 kilometres in diameter. These are surrounded by a 100 to 300-metre-wide hornfels

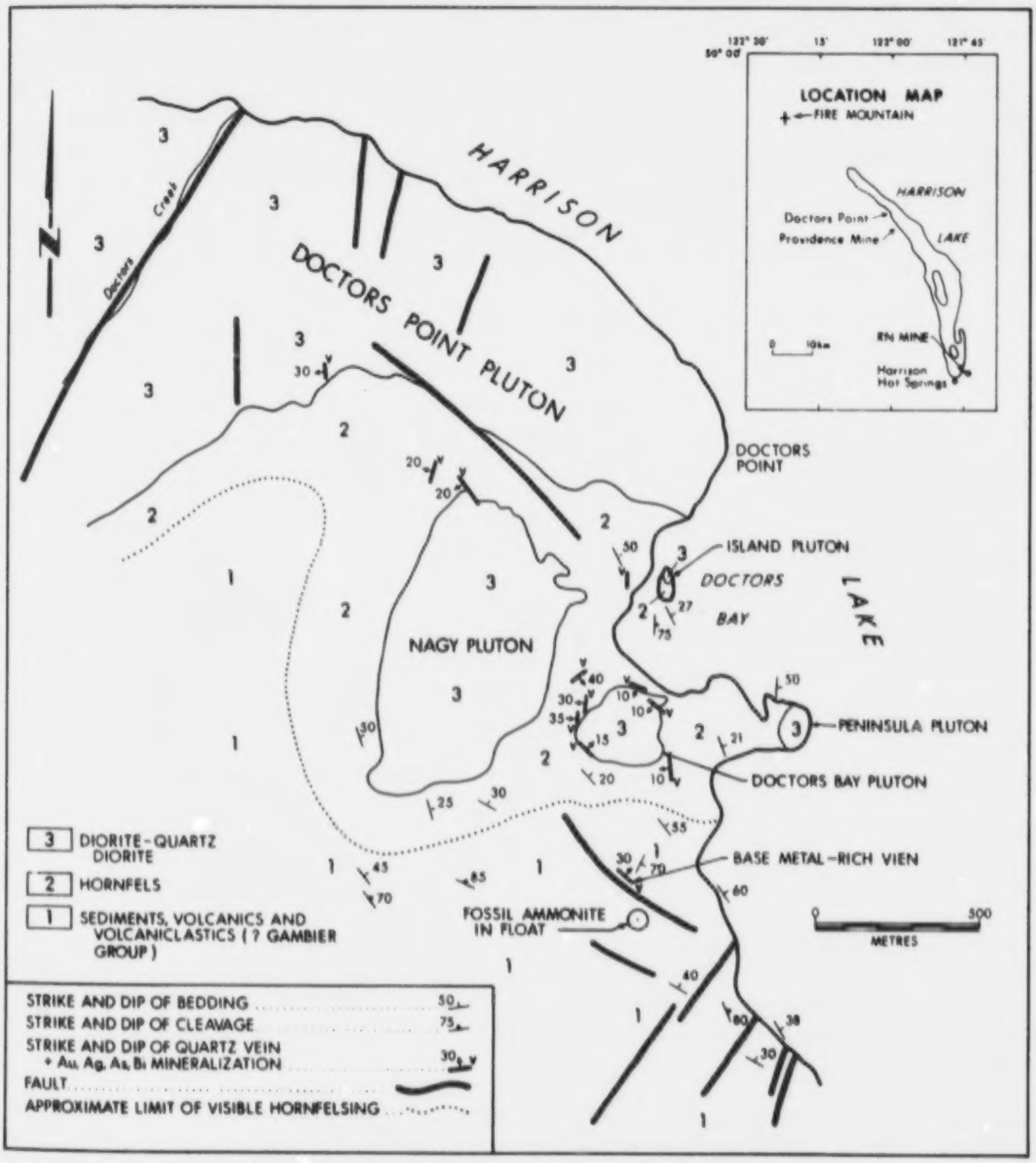

N
HARRISON
LAKE
Doctors Creek
DOCTORS POINT PLUTON
DOCTORS POINT
ISLAND PLUTON
DOCTORS BAY
NAGY PLUTON
PENINSULA PLUTON
DOCTORS BAY PLUTON
BASE METAL-RICH VIEN
FOSSIL AMMONITE IN FLOAT
0
500
METRES
LOCATION MAP
FIRE MOUNTAIN
HARRISON LAKE
Doctors Point
Providence Mine
RN MINE
Harrison Hot Springs
0
10km
122° 30'
15'
122° 00'
121° 45'
50° 00'
3 DIORITE-QUARTZ DIORITE
2 HORNFELS
1 SEDIMENTS, VOLCANICS AND VOLCANICLASTICS (? GAMBIER GROUP)
STRIKE AND DIP OF BEDDING
STRIKE AND DIP OF CLEAVAGE
STRIKE AND DIP OF QUARTZ VEIN + Au, Ag, As, Bi MINERALIZATION
FAULT
APPROXIMATE LIMIT OF VISIBLE HORNFELSING

Figure 34. Geology of the Doctors Point area, Harrison Lake.

aureole marked by pervasive recrystallization, the growth of fine-grained biotite, and the local development of cordierite, andalusite, and pyrite-pyrrhotite. The gold-silver mineralization is hosted in narrow, gently dipping, vuggy quartz-sulphide veins that show an overall spatial association to the pluton margins (Fig. 34) and which have followed pre-existing low angle fractures; these probably represent cone sheet-type fractures formed during the diorite intrusion. Veins are found in 12 separate localities (Fig. 34), 11 of which are underlain by either diorite or hornfelsic rocks. These veins generally contain moderate to high gold values and are enriched in arsenopyrite and pyrite with traces of galena and sphalerite. However, the southernmost mineralized fracture (Fig. 34) lies outside the hornfelsic aureole that surrounds the plutons. Furthermore, it is not associated with quartz veining and contains little gold, but is enriched in silver, lead, zinc, and arsenic. This zone contains pyrite, arsenopyrite, tetrahedrite, and galena, together with alteration minerals that include scorodite, anglesite ($PbSO_4$), schultenite ($PbHAsO_4$), jarosite, and malachite (J. Kwong, personal communication, 1984). Thus, a temperature-related mineral and element zoning probably exists in the area, with gold being found closer to the pluton margins and base metals predominating outside the hornfelsic envelope.

The age of the volcano-sedimentary sequence is uncertain. Monger (1970) included these rocks within the Upper Jurassic Mysterious Creek Formation, while Ray, *et al.* (1984) suggested that the sequence belongs to the Middle Jurassic Harrison Lake Group (Crickmay, 1925). However, Mr. Neil Froc of Rhyolite Resources Inc. discovered an ammonite fossil in the area (Fig. 34), which was identified by Dr. H. Tipper (personal communication, 1984) as *Cleoniceras perezianum* of Middle Albian age. Thus the sequence at Doctors Point is probably Early Cretaceous in age, and possibly represents a lateral equivalent to the Gambier Group. The fossil was found in float at the base of an old roadside outcrop of grey, cherty tuff below British Columbia Hydro tower No. 36-1. Identical lithologies make it probable that the fossil-bearing float was derived from the adjacent outcrop, although a systematic search in the immediate vicinity failed to locate further fossils.

Biotite and hornblende samples extracted from the Doctors Bay pluton (Fig. 34) are currently undergoing K/Ar analysis for age dating. However, a preliminary estimate of *circa* 25 Ma from the biotite (J. Harakal, personal communication, 1984) suggests the diorite bodies were contemporaneous with gold-bearing veins at the RN mine, approximately 45 kilometres to the southeast. Thus, a synchronous event characterized by regional plutonism and gold mineralization probably took place along the Harrison Lake fracture system in Late Oligocene-Early Miocene time.

Contrary to preliminary conclusions of Ray, *et al.* (1984), the mineralization at Doctors Point is now believed to be genetically and temporally related to the diorite plutons and probably represents a late hydrothermal phase of this magmatic event. The Nagy and Doctors Bay plutons (Fig. 34), and the siliceous hornfels immediately adjacent to their margins, locally contain abundant pyrite and pyrrhotite, although these sulphide-rich pockets are not enriched in gold or silver. The gold-silver mineralization postdates both the intrusion of the plutons and a late suite of mafic dykes. The postulated sequence is: (1) emplacement of the diorite plutons with some barren sulphide mineralization, accompanied by low angle cone sheet fracturing in the hornfels aureole (Fig. 35); (2) intrusion of the mafic dykes; (3) minor thrust faulting along the fractures; (4) gold-silver-arsenic mineralization along some of the cone sheet fractures; and (5) late subvertical faulting. Veins generally dip toward the pluton cores and are associated mostly with the Doctors Bay pluton, although a few veins lie within or adjacent to the Doctors Point and Nagy plutons (Fig. 34). This suggests that the five diorite bodies in the area are related and probably represent apophyses of a single major body.

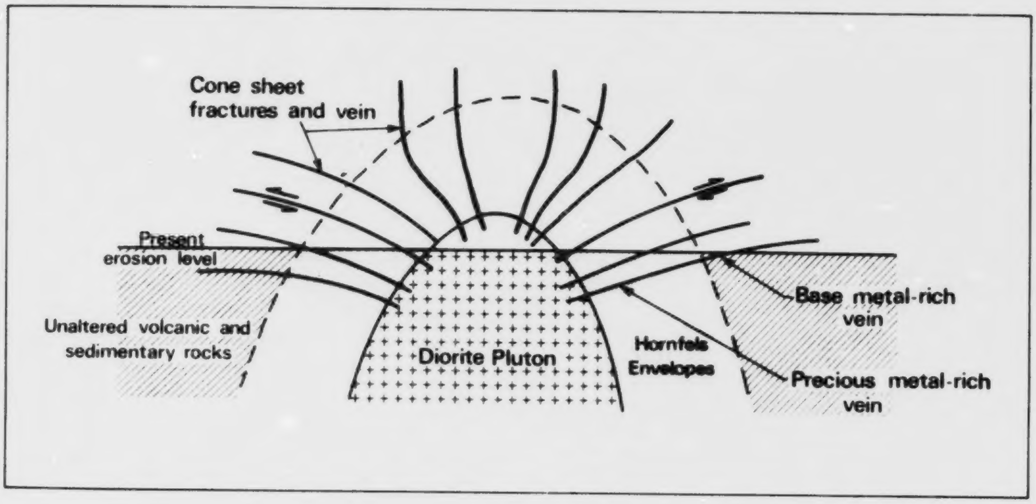

Cone sheet fractures and vein
Present erosion level
Unaltered volcanic and sedimentary rocks
Diorite Pluton
Hornfels Envelopes
Base metal-rich vein
Precious metal-rich vein

Figure 35. Model depicting development of cone sheet fracturing and associated veins to explain Doctors Point mineralization (adapted after Anderson and Jeffreys, 1936).

FIRE MOUNTAIN-FIRE LAKE AREA

INTRODUCTION

This area, situated approximately 25 kilometres northwest of the north end of Harrison Lake (Fig. 34), is underlain by the Upper Jurassic to Lower Cretaceous Fire Lake Group (Roddick, 1965), a 4 500-metre-thick sequence of largely sedimentary rocks with lesser amounts of volcanic greenstone. The Fire Lake camp (Ditson, 1978) includes six mineralized veins, five of which are clustered in the vicinity of Fire Mountain (Fig. 38; Table 2). All are quartz veins hosted in greenstones and they carry chalcopyrite and sporadic native gold. Two of the veins, the Money Spinner and the Blue Lead (Mineral Inventory 92G/NE-2 and 92G/NE-4), were visited and sampled during this study. The sixth vein, the Dandy (Mineral Inventory 92G/NE-10), which lies 10 kilometres northwest of Fire Mountain, is a lead-zinc-bearing quartz carbonate vein hosted in brecciated sedimentary rocks (Ditson, 1978).

TABLE 2
AREAS WITH MINERALIZED VEINS ASSOCIATED WITH THE HARRISON LAKE FRACTURE SYSTEM

Name	MI No.	Host Type	Gangue	Reported Mineralization
Money Spinner	92G/NE-2	Greenstone	Quartz	Cu-Au
Barkoola	92G/NE-3	Greenstone	Quartz	Cu-Au
Blue Lead	92G/NE-4	Greenstone	Quartz	Cu-Au
King No. 1 (Star)	92G/NE-5	Greenstone	Quartz	Cu-Au
Richfield	92G/NE-6	Greenstone	Quartz	Au
Dandy (Mayflower)	92G/NE-10	Brecciated sedimentary rocks	Quartz-carbonate	Pb-Zn-Ag-Au
Doctors Point (Nagy)	92H/NW-71	Diorite and hornfelsed volcanic and sedimentary rocks	Quartz	Au-Ag-As-Bi
Providence Mine	92H/NW-30	Greenstone	Quartz-carbonate	Pb-Zn-Ag-Au
RN Mine (Geo)	92H/SW-92	Diorite	Quartz	Cu-Au

GEOLOGY OF THE FIRE MOUNTAIN-FIRE LAKE AREA

Details of a single geological traverse over the area are on Figure 36, and a geological section across the 2 500-metre-thick, northeasterly dipping succession is shown on Figure 37. Bedding-cleavage intersections and minor fold structures indicate that the section occupies the northern limb of a major, southeast-trending antiform (Fig. 37). Vague graded bedding in some wacke horizons suggests the sequence is upright, and apart from local areas of tight folding north of Fire Mountain (Fig. 37), there is no evidence of major structural repetition in the succession.

Three broad divisions are recognized in the succession: a lower 700-metre-thick volcanic greenstone unit with possible subvolcanic intrusive rocks, an intermediate 1 000-metre-thick sequence of mainly wacke, conglomerate, and volcaniclastic rocks, and an upper 800-metre-thick unit of argillite and minor amounts of wacke. The upper unit consists largely of poorly bedded, well-cleaved, black to grey slaty argillites that are generally pyritiferous. These are locally interbedded with siltstones, while on the northern slopes of Fire

Mountain there are thin, tightly folded horizons of lithic wacke containing 8 to 15-centimetre-thick beds of marl and impure limestone. These calcareous beds are tightly folded, disrupted, and boudined.

The middle unit includes abundant green-coloured wacke, lithic wacke, and water-lain tuff that locally shows graded bedding. Other rock types include conglomerates with angular to subrounded felsic and intermediate volcanic clasts up to 8 centimetres in diameter, together with green to grey, volcanogenic siltstone that display rare ripple markings and grading. The middle unit also includes minor amounts of volcanic breccia, rare thin mafic flows, and some aquagene breccias.

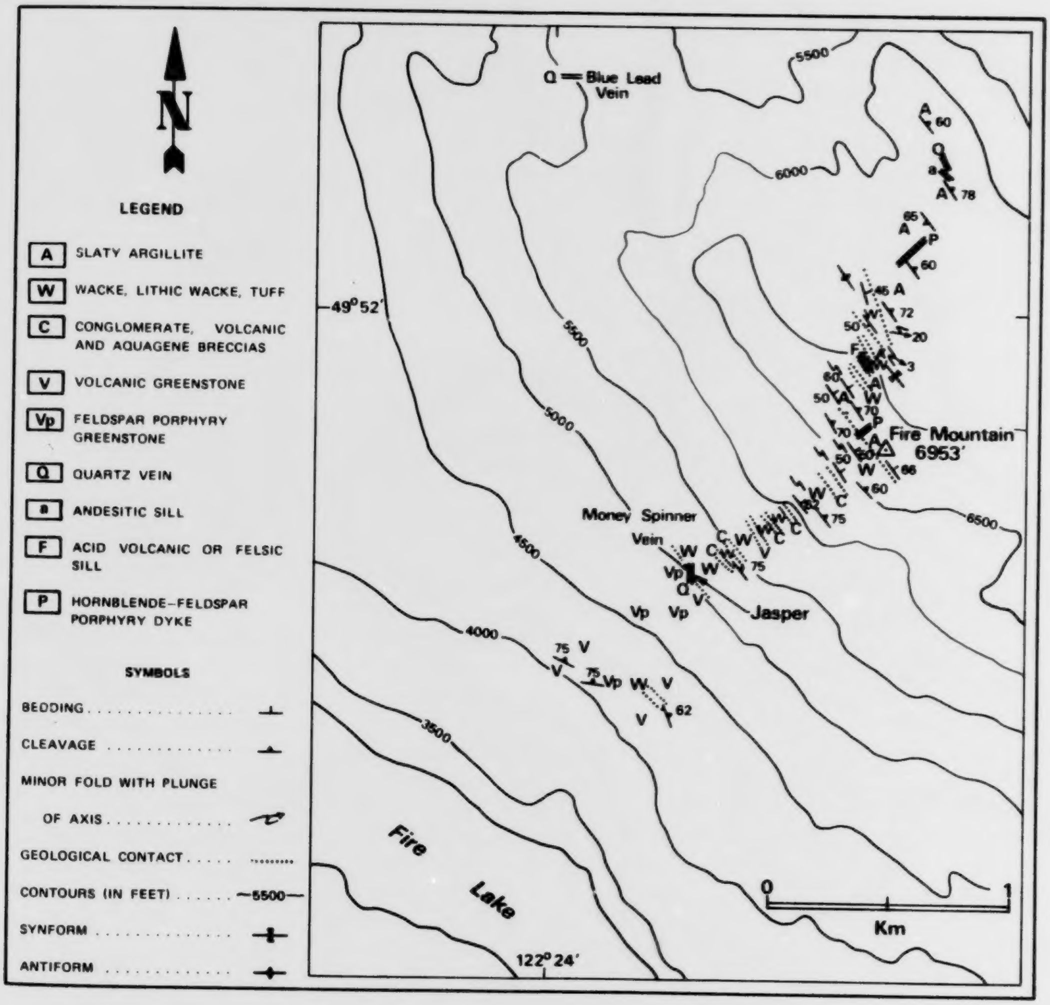

N
LEGEND
A SLATY ARGILLITE
W WACKE, LITHIC WACKE, TUFF
C CONGLOMERATE, VOLCANIC AND AQUAGENE BRECCIAS
V VOLCANIC GREENSTONE
Vp FELDSPAR PORPHYRY GREENSTONE
Q QUARTZ VEIN
a ANDESITIC SILL
F ACID VOLCANIC OR FELSIC SILL
P HORNBLENDE-FELDSPAR PORPHYRY DYKE
SYMBOLS
BEDDING
CLEAVAGE
MINOR FOLD WITH PLUNGE OF AXIS
GEOLOGICAL CONTACT
CONTOURS (IN FEET) —5500—
SYNFORM
ANTIFORM
Q ═ Blue Lead Vein
49°52'
122°24'
5500
6000
5000
4500
4000
3500
6500
Fire Mountain 6953'
Money Spinner Vein
Jasper
Fire Lake
0
1
Km

Figure 36. Geology between Fire Lake and Fire Mountain.

The lower unit (Fig. 37) comprises massive, fine-grained, equigranular volcanic greenstone, and porphyritic greenstone characterized by rounded feldspar phenocrysts up to 1 centimetre in diameter. It is uncertain whether the porphyritic greenstone is an extrusive or a subvolcanic intrusive rock. Locally the lower unit includes minor amounts of volcanic wacke and bedded tuff, together with volcanic breccia containing clasts up to 2 centimetres in diameter. Highly disrupted layers, lenses, and pods of red jasper up to 0.3 metre thick occur in the vicinity of the Money Spinner adit, close to the contact between the lower and middle units. The massive to finely banded jasper is associated with aquagene and volcanic breccias and bedded tuffs, and contains disseminated magnetite and specular hematite with traces of chalcopyrite and malachite. No attempt was made to trace the jasper-bearing horizon along strike, but malachite-stained, jasper-bearing float was noted at several locations in scree material for approximately 200 metres northwest of the Money Spinner adit. Jasper at the volcanic-sediment interface could indicate submarine exhalitive activity, which suggests that the Fire Lake Group is a viable exploration target for massive sulphide mineralization.

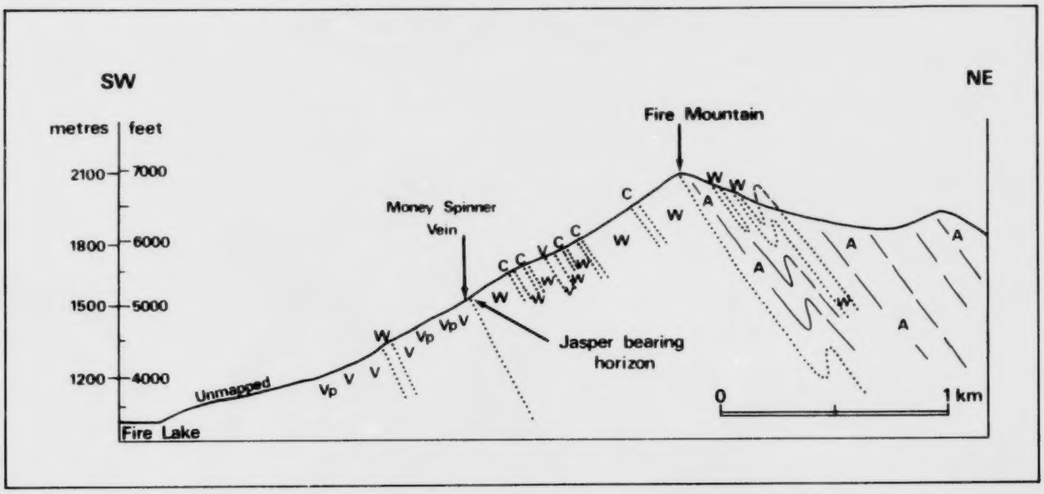


Figure 37. Southwest-northeast geological section through Fire Mountain (for symbols see Fig. 36).

The area was affected by one episode of regional folding which produced major and minor folds with southeast-striking, steep northeast-dipping axial surfaces and gentle to moderate, southeasterly plunging axes. This deformation was accompanied by development of a slaty cleavage in the argillites and some wackes, and the local development of a fracture cleavage in the greenstones. The argillites were deformed subsequently by late kink folds whose axial surfaces strike east-northeast and along which there has been local faulting and the subsequent injection of narrow quartz veins. As well as the Money Spinner and Blue Lead veins, other quartz veins noted in the area include a 0.3-metre-wide, southeasterly striking, muscovite and pyrite-bearing vein approximately 1.5 kilometres north of Fire Mountain (Fig. 36) and numerous irregular, gash-filling veins within wackes and lithic wackes south of Fire Mountain. These are steep to gently inclined and up to 0.4 metre wide; they contain milky quartz and minor amounts of feldspar but no sulphides.

Small-scale intrusions in the area include late, 0.5 to 3-metre-wide, northeasterly trending dykes of felsic, amphibole-bearing feldspar porphyry that intrude the argillites. Some dykes follow the disrupted axial planar surfaces of the kink folds, but postdate the thin quartz veins. It is uncertain whether an outcrop of pale, fine-grained feldspar porphyry within the argillites 0.3 kilometre north of Fire Mountain is an acid volcanic flow or an intrusive rock. Approximately 0.75 kilometre further north, a single, deeply weathered 4-metre-wide andesitic sill intrudes the slaty argillites (Fig. 36).

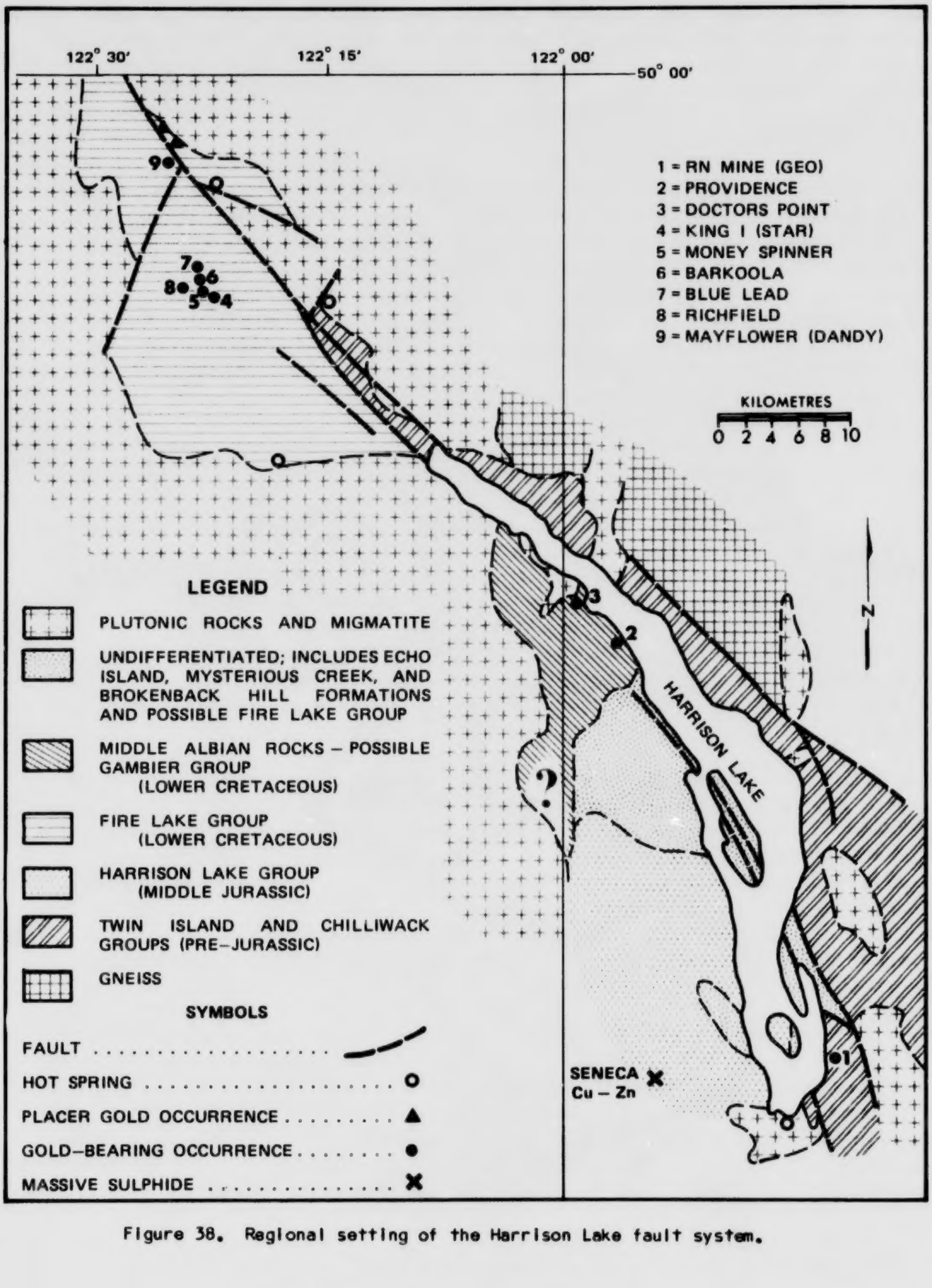
GEOLOGY OF THE MONEY SPINNER AND BLUE LEAD VEINS

The Money Spinner vein, situated approximately 1 kilometre southwest of Fire Mountain (Fig. 36), was discovered and worked in the 1890's and some subsequent work was done in the 1930's. Approximately 180 metres of underground workings were driven on the property, and reportedly the vein was exposed for over 300 metres on surface (Roddick, 1965). Both the vein and the host rocks are well exposed at the entrance to the collapsed main adit, which lies immediately above the old waste dump. The remains of a shorter tunnel are discernible approximately 40 metres lower down the hillside.

The 1 to 1.3-metre-wide vein strikes north-south and dips 65 degrees west. It has a ribboned appearance, comprising layers of white quartz between 0.5 to 2.5 centimetres wide separated by thin partings of black, sheared chlorite. Many quartz crystals are elongated parallel to the layering and exhibit a pronounced mineral lineation that plunges 35 degrees toward a 205-degree direction. The vein contains variable amounts of chalcopyrite with traces of bornite and sericite and some rare quartz-lined vuggy cavities. In parts the vein is malachite stained but no visible gold was detected.

Most of the vein material on the waste dump comprises ribboned, chalcopyrite-bearing quartz, similar to that in the vein outcrop. However, the dump also contains material not seen on surface; this consists of very coarse-grained, randomly orientated quartz intergrown with crystalline masses of pale brown calcite. Trace amounts of fine sericite and dravite (tourmaline) were identified (J. Kwong, personal communication, 1984), but no sulphides or gold were seen.

The westerly dipping Money Spinner vein has sharp margins and lies within a north-south-striking fault. The hangingwall consists of feldspar



122° 30′
122° 15′
122° 00′
50° 00′
1 = RN MINE (GEO)
2 = PROVIDENCE
3 = DOCTORS POINT
4 = KING I (STAR)
5 = MONEY SPINNER
6 = BARKOOLA
7 = BLUE LEAD
8 = RICHFIELD
9 = MAYFLOWER (DANDY)
KILOMETRES
0 2 4 6 8 10
N
HARRISON LAKE
?
SENECA Cu – Zn
LEGEND
PLUTONIC ROCKS AND MIGMATITE
UNDIFFERENTIATED; INCLUDES ECHO ISLAND, MYSTERIOUS CREEK, AND BROKENBACK HILL FORMATIONS AND POSSIBLE FIRE LAKE GROUP
MIDDLE ALBIAN ROCKS – POSSIBLE GAMBIER GROUP (LOWER CRETACEOUS)
FIRE LAKE GROUP (LOWER CRETACEOUS)
HARRISON LAKE GROUP (MIDDLE JURASSIC)
TWIN ISLAND AND CHILLIWACK GROUPS (PRE-JURASSIC)
GNEISS
SYMBOLS
FAULT
HOT SPRING ○
PLACER GOLD OCCURRENCE ▲
GOLD-BEARING OCCURRENCE ●
MASSIVE SULPHIDE ✖

Figure 38. Regional setting of the Harrison Lake fault system.

porphyry greenstone, while the footwall comprises highly altered, green-coloured tuff, wacke, and aquagene breccia that locally carries thin, disrupted jasper horizons. The preferred orientation of quartz crystals in the vein and the interpreted displacement of the stratigraphy suggest that the hangingwall moved upward and southward relative to the footwall.

The Blue Lead vein, which lies about 2 kilometres northwest of Fire Mountain (Fig. 36), was visited by one author (S. Coombes) during this present survey. The vein varies from 20 to 60 centimetres in thickness, strikes east-west, and dips approximately 50 degrees north. The vein material resembles the white ribbon-textured quartz outcropping at the Money Spinner adit and contains thin, dark chloritic laminae orientated parallel to the sharp vein margins. The malachite-stained quartz contains occasional small vugs, as well as minor amounts of chalcopyrite and traces of sericite, hematite, dravite (tourmaline), and visible native gold. A subparallel, 10 to 30-centimetre-thick quartz vein occurs 5 metres north of the main vein, but this apparently carries no sulphides. A 10-metre-long decline has been driven down the main vein, and the host rocks comprise green-coloured, faintly layered rocks that are interpreted to be an interbedded sequence of volcanogenic sedimentary rocks and greenstones.

CONCLUSIONS

All known mineralization associated with the Harrison Lake fracture system (Fig. 38; Table 2) appears to be vein type (Ray, *et al.*, 1984) that, on the basis of vein mineralogy and host rock lithology, can be broadly separated into three types:

(1) Gold-bearing quartz veins which have variable precious metal and sulphide mineralization but are genetically and temporally related to a 25-Ma episode of regional diorite plutonism. These veins are seen at Doctors Point and at the RN mine (Fig. 38).

(2) Quartz veins in the vicinity of Fire Mountain (Fig. 38) which are hosted in greenstones and carry sporadic free gold and chalcopyrite. The Money Spinner and Blue Lead are examples of this type.

(3) Quartz carbonate veins carrying galena, sphalerite, silver, and gold; these occur at the Providence mine (Mineral Inventory 92H/NW-30) and probably comprise the Dandy vein.

The mineralized veins at Doctors Point are related to dioritic plutons which preliminary K/Ar dating suggests are 25 Ma in age. This date coincides with a K/Ar of 24.5 Ma from gold-bearing veins associated with similar dioritic rocks at the defunct RN mine at the southern end of Harrison Lake (Fig. 38). Thus, the gold mineralization at both localities may form part of a synchronous, regional, magmatic-related Tertiary event along the Harrison Lake fracture system. This episode is also coeval with some ages obtained from both the Mount Barr and Chilliwack batholiths (Richards and White, 1970), which lie along a projected southeasterly extension of the Harrison Lake fracture system.

The veins at Doctors Point exhibit a close spatial relationship to the margins of the plutons and were controlled by pre-existing, gently inclined cone sheet-type fractures that developed during forcible intrusion of the diorite (Fig. 35). Some temperature-related precious and base metal zoning is apparent within the vein system, and recognition of the cone sheet fracture control may help locate other mineralized veins in the district.

Fossil evidence indicates that the volcanic and sedimentary sequence hosting the diorite bodies at Doctors Point are Middle Albian in age, and thus may be lateral equivalents to the Gambier Group (Armstrong, 1953; Roddick, 1965), which elsewhere hosts the Brittania and Northair deposits (Barr, 1980; Payne, *et al.*, 1980). This, and the presence of andesitic and acid volcanic and pyroclastic rocks at Doctors Point, suggests that the area warrants exploration for Kuroko-type, massive sulphide mineralization. Likewise, the recognition of a jasper-bearing exhalite horizon on Fire Mountain also indicates that parts of the Fire Lake Group may have massive sulphide potential.

ACKNOWLEDGMENTS

The authors wish to thank the management and staff of Rhyolite Resources Inc. and Aquarius Resources Ltd. for their active cooperation. Particular thanks are also due to B. N. Church for useful discussions in the field, H. Tipper for fossil identification, M. Fournier for assistance in the field, and to the staff of the Ministry of Energy, Mines and Petroleum Resources' Laboratory for analytical and X-ray work.

REFERENCES

Anderson, E. M. and Jeffreys, H. (1936): The Dynamics of the Formation of Cone-sheets, Ring-dykes, and Caldron-subsidence, *Roy. Soc. Edinburgh*, Proc., Vol. 56, No. 2, pp. 128-163.

Armstrong, J. E. (1953): Vancouver North Map-area, British Columbia, *Geol. Surv., Canada*, Paper 53-28.

Barr, D. A. (1980): Gold in the Canadian Cordillera, *C.I.M.*, Bull., Vol. 73, No. 818, pp. 59-76.

Crickmay, C. H. (1925): The Geology of the Harrison Lake District, unpub. Ph.D. thesis, *Standford Univ.*, Ohio, California.

Ditson, G. M. (1978): Metallogeny of the Vancouver-Hope Area, British Columbia, unpub. M.Sc. thesis, *Univ. of British Columbia*, May 1978.

Monger, J.W.H. (1970): Hope Map-area, West Half (92H W1/2), British Columbia, *Geol. Surv., Canada*, Paper 69-47, 75 pp.

Payne, J. G., Bratt, J. A., and Stone, B. G. (1980): Deformed Mesozoic Volcanogenic Cu-Zn Sulphide Deposits in the Britannia District, British Columbia, *Econ. Geol.*, Vol. 75, pp. 700-721.

Ray, G. E., Coombe, S., and White, G. (1984): Harrison Lake Project (92H/5, 12; 92G/9), *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1983, Paper 1984-1, pp. 42-53.

Richards, T. A., and White, W. H. (1970): K/Ar Ages of Plutonic Rocks between Hope, British Columbia, and the 49th Parallel, *Cdn. Jour. Earth Sci.*, Vol. 7, pp. 1203-1207.

Roddick, J. A. (1965): Vancouver North, Coquitlam, and Pitt Lake Map-areas, British Columbia, *Geol. Surv., Canada*, Mem. 335.

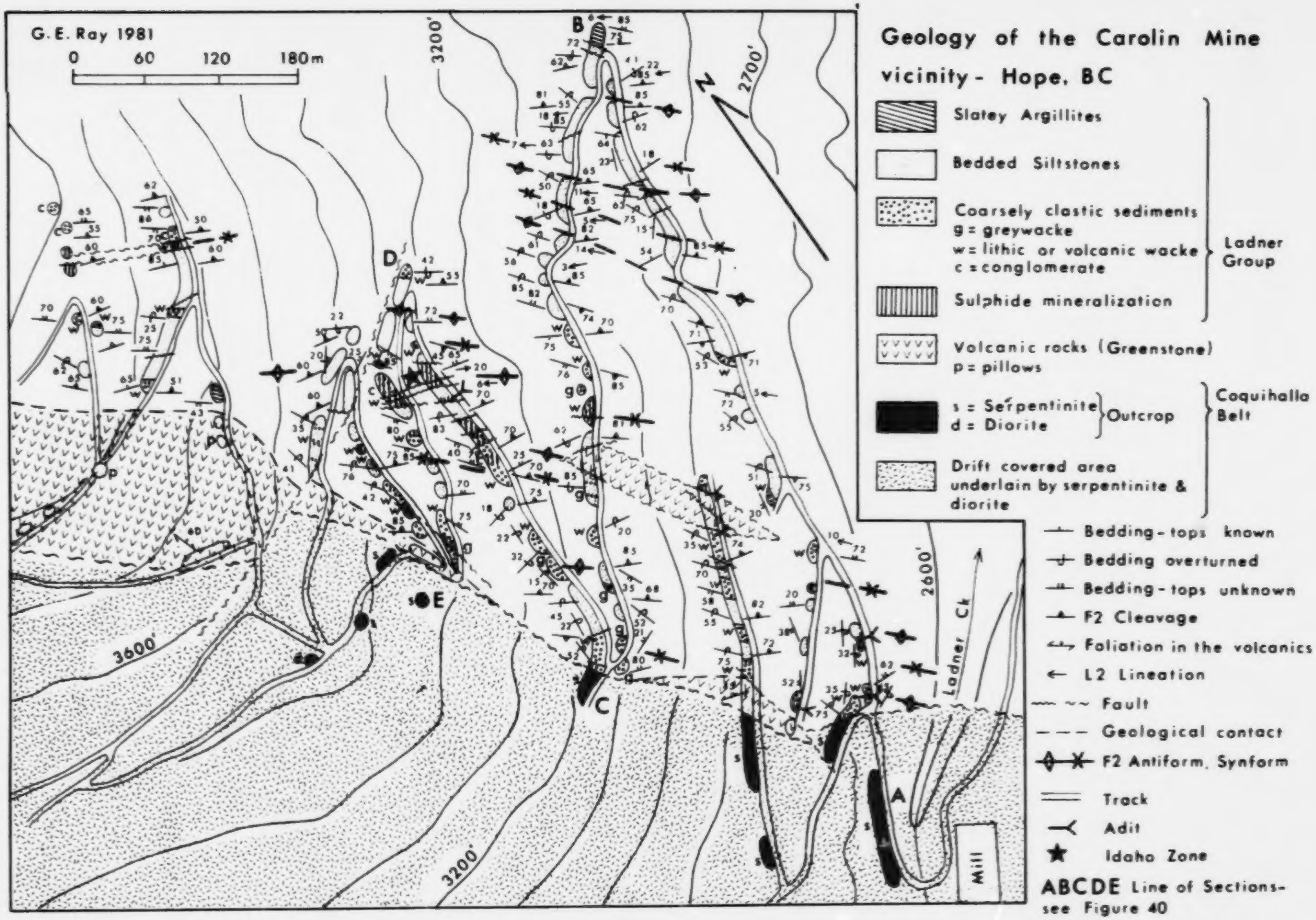

G.E. Ray 1981
0
60
120
180m
Geology of the Carolin Mine vicinity - Hope, BC
Slatey Argillites
Bedded Siltstones
Coarsely clastic sediments
g = greywacke
w = lithic or volcanic wacke
c = conglomerate
Sulphide mineralization
Ladner Group
Volcanic rocks (Greenstone)
p = pillows
s = Serpentinite
d = Diorite
Outcrop
Coquihalla Belt
Drift covered area underlain by serpentinite & diorite
Bedding - tops known
Bedding overturned
Bedding - tops unknown
F2 Cleavage
Foliation in the volcanics
L2 Lineation
Fault
Geological contact
F2 Antiform, Synform
Track
Adit
Idaho Zone
ABCDE Line of Sections - see Figure 40
N
2700'
2600'
3200'
3600'
Ladner Ck
Mill
A
B
C
D
E

Figure 39. Geology of the Carolin mine vicinity, Hope, British Columbia.

SURFACE AND UNDERGROUND GEOLOGICAL STRUCTURES AT THE CAROLIN GOLD MINE

(92H/11)

By G. E. Ray
Ministry of Energy, Mines and Petroleum Resources
and
R.J.E. Niels
Carolin Mines Ltd.

INTRODUCTION

The Carolin mine gold deposit is situated about 20 kilometres northeast of Hope. The complex, replacement-type mineralization is hosted in Jurassic metasedimentary rocks of the Ladner Group, close to both their unconformable contact with Early Triassic (?) volcanic greenstones and their faulted contact with ultramafic rocks of the Coquihalla serpentine belt (Fig. 39). The mine started regular production in 1982; ore reserves at that time were reported to be 1.5 million tonnes averaging 4.8 grams gold per tonne, at a cutoff grade of 2.7 grams gold per tonne.

The sulphide-albite-quartz-gold mineralization is both lithologically and structurally controlled within the hinge regions of large scale antiformal folds (Shearer and Niels, 1983). Both the major and minor geological structures mapped on surface at Carolin mine (Figs. 39 and 40) can be correlated with these subsurface, ore-controlling folds. This report presents an analysis of the surface structural data which can be used to predict the orientation and geometry of the ore-related folds.

GEOLOGICAL STRUCTURE AT CAROLIN MINE

The structural history of the mine area is shown in Table 1. The first deformational episode resulted in tectonic inversion of both the Ladner Group and the older greenstone sequence, although no related folds or structural planar fabrics from this episode have been recognized. The second deformational event (D2) produced the dominant fold pattern in the mine area (Table 1). This formed upright, concentric to overturned and asymmetric minor and major folds; the major structures have wavelengths of 60 to 110 metres and amplitudes between 25 and 50 metres (Fig. 40; Ray, 1982). The D2 event was associated with the imposition of a weak to intense axial planar slaty cleavage in the siltstones and argillites, together with a well-marked bedding-cleavage intersection lineation orientated subparallel to the fold axes. This cleavage and mineral lineation is generally absent in the coarse-grained wacke units.

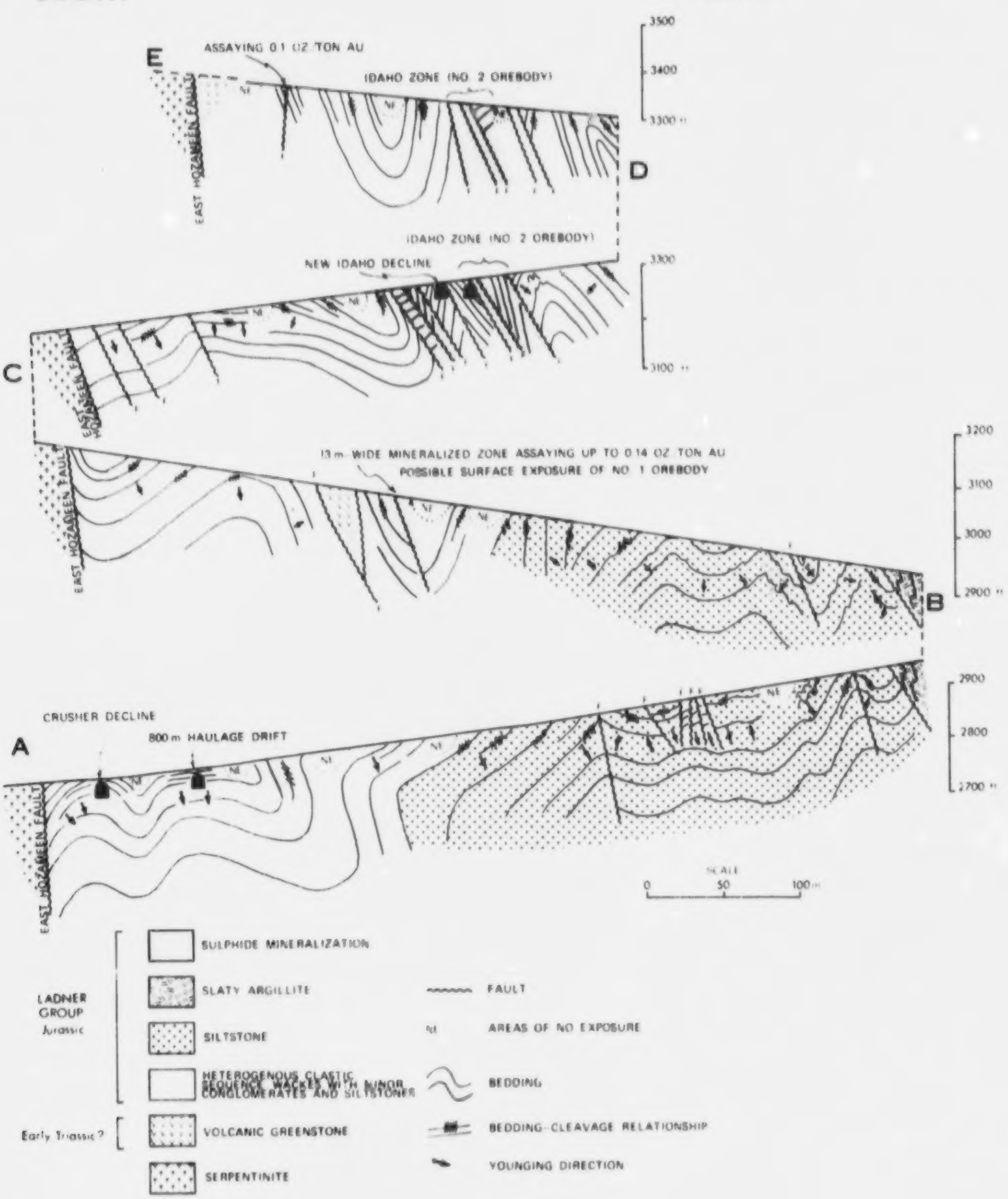

SOUTH
NORTH
E
ASSAYING 0.1 OZ TON AU
IDAHO ZONE (NO. 2 OREBODY)
3500
3400
3300 ft
D
EAST HOZAMEEN FAULT
IDAHO ZONE (NO. 2 OREBODY)
NEW IDAHO DECLINE
3300
3100 ft
C
EAST HOZAMEEN FAULT
13 m WIDE MINERALIZED ZONE ASSAYING UP TO 0.14 OZ TON AU
POSSIBLE SURFACE EXPOSURE OF NO. 1 OREBODY
3200
3100
3000
2900 ft
B
EAST HOZAMEEN FAULT
CRUSHER DECLINE
800 m HAULAGE DRIFT
A
2900
2800
2700 ft
EAST HOZAMEEN FAULT
NE
SCALE
0
50
100 m
LADNER GROUP
Jurassic
Early Triassic?
SULPHIDE MINERALIZATION
SLATY ARGILLITE
SILTSTONE
HETEROGENOUS CLASTIC SEQUENCE WACKES WITH MINOR CONGLOMERATES AND SILTSTONES
VOLCANIC GREENSTONE
SERPENTINITE
FAULT
AREAS OF NO EXPOSURE
BEDDING
BEDDING-CLEAVAGE RELATIONSHIP
YOUNGING DIRECTION

Figure 40. Geological sections across the Carolin mine area.

TABLE 1
HISTORY OF EVENTS IN CAROLIN MINE AREA

Age	Event
	Late faulting - southeast-trending set followed by a northeast to east-northeastly striking set.
	Large scale dextral strike-slip movement along the Hozameen fault.
39 Ma	Intrusion of the Needle Peak pluton and related felsic dyke swarm.
Middle to Late Cretaceous	D3 - Asymmetric folding. Local kink folding and strain slip cleavage development.
Middle to Late Cretaceous	D2 - Major concentric to similar-type, open to tight asymmetric folding with southeast-striking axial planes and gently inclined, northwest-plunging axes. Development of regional slaty cleavage and mineral lineation.
Middle to Late Cretaceous	D1 - Easterly directed thrusting along the Hozameen fault causing local structural inversion of the Ladner Group and older volcanic greenstones.
Early Jurassic to Early Cretaceous	Deposition of the Ladner Group and other younger sedimentary rocks of the Pasayten trough.
	UUUUUU Unconformity
Early Triassic (?)	Greenstone volcanic eruption.

The geological cross-sections on Figure 40, together with a stereoplot of poles to bedding (Fig. 42A), show that most of the D2 structures in the mine area are open to tight, concentric, upright folds. These have southeasterly striking axial planes that dip steeply northeast at an average of 75 degrees (Fig. 42B). Lineation plots (Fig. 42C) reveal that the D2 fold axes have an average plunge of 12 degrees in a northwesterly direction; this is essentially similar to the estimated 20-degree northwesterly plunge of both the Carolin mine orebody and the axes of its controlling antiformal structures (Shearer and Niels, 1983).

While most D2 folds in the mine area are concentric and upright (Fig. 42A), there is the local development of tighter, asymmetric, similar-style folds that are overturned to the southwest (Fig. 40). Many of these small scale, overturned structures have disrupted, faulted hinge zones along which quartz veins are locally injected (Fig. 41); an identical pattern of fold hinge disruption is recognized in the large scale, ore-controlling, overturned folds mapped underground (Shearer and Niels, 1983). Figures 42D and 42E show that both the late faulting and quartz veining in the mine area are controlled strongly by the D2 slaty cleavage, and not by the bedding.

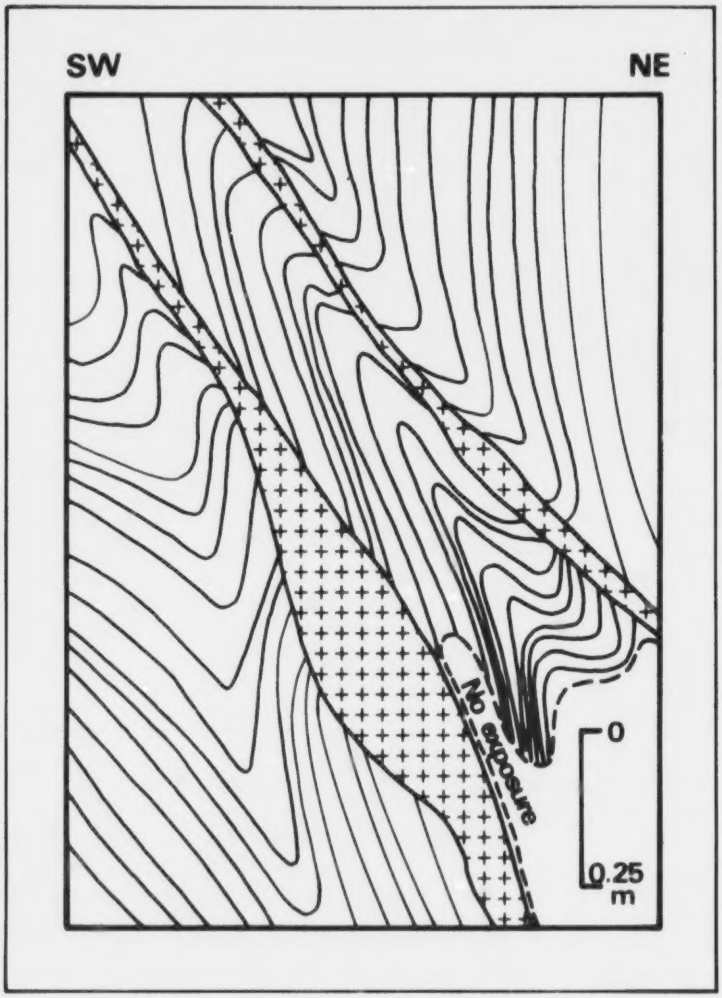


Figure 41. D2 similar-type folds in Ladner Group bedded siltstones. Note quartz veins (cross pattern) and disrupted hinge zones. (Taken from photograph of road outcrop, 290 metres east-northeast of old Idaho adit, Carolin mine).

CONCLUSIONS

The dominant (D2) fold episode deforming the Ladner Group in the Carolin mine area produced mostly upright, concentric, open to tight structures. Locally, however, tighter, asymmetric, similar-style D2 folds were developed; these are overturned to the southwest and often have disrupted, faulted hinge zones.

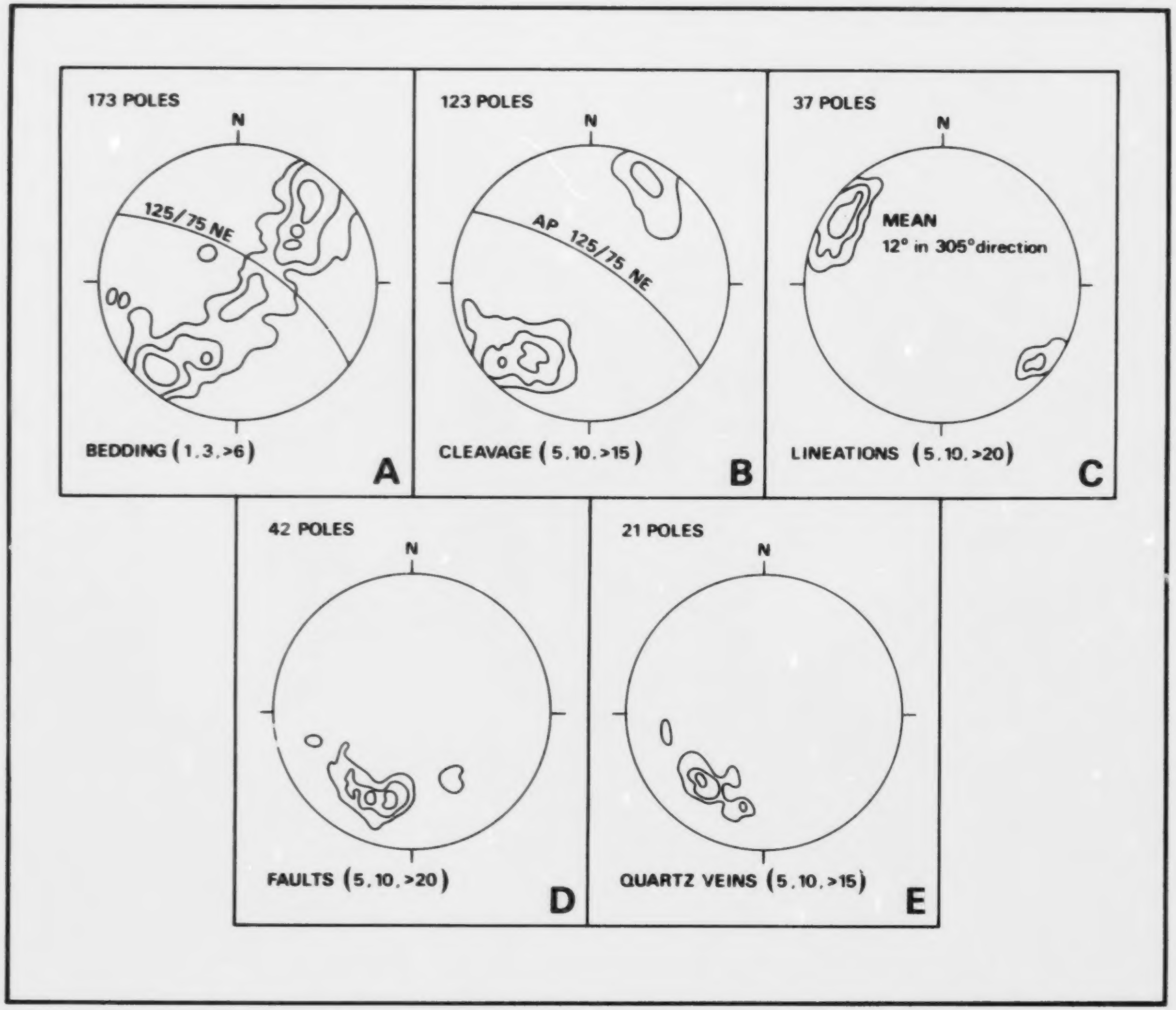

173 POLES
N
125/75 NE
BEDDING (1,3,>6)
A
123 POLES
N
AP 125/75 NE
CLEAVAGE (5,10,>15)
B
37 POLES
N
MEAN
12° in 305° direction
LINEATIONS (5,10,>20)
C
42 POLES
N
FAULTS (5,10,>20)
D
21 POLES
N
QUARTZ VEINS (5,10,>15)
E

Figure 42. Ladner Group - Carolin mine (surface). Lower hemisphere equal area projection. A - poles to bedding; B - poles to slaty cleavage; C -mineral lineations; D - faults; E - quartz veins. Numbers in brackets are contour intervals in per cent.

The mineralization at Carolin mine is largely confined to favourable lithological horizons within the hinge portions of large scale D2 antiformal folds (Shearer and Niels, 1983). These ore-controlling structures are identical in style to the overturned, asymmetric folds with disrupted hinge zones seen on surface at Carolin mine (Fig. 41). They have axes that plunge gently northwest and southeasterly striking axial planes that dip steeply northeast.

The temporal relationship between the gold mineralization and the D2 folding is unknown, although some of the associated quartz veins in the deposit have followed the slaty cleavage; this suggests mineralization either accompanied or succeeded the D2 structural episode. The orientation of the later faulting, which displaces the ore zones (Shearer and Niels, 1983), has also been largely controlled by the axial planar slaty cleavage rather than the sedimentary bedding; this fracturing is concentrated preferentially in the fold hinge areas.

ACKNOWLEDGMENTS

The authors wish to thank the management and staff of Carolin Mines Ltd. for their cooperation. Discussions with W. Kilby and T. Höy are gratefully acknowledged.

REFERENCES

Ray, G. E. (1982): Carolin Mine-Coquihalla Gold Belt Project, *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1981, Paper 1982-1, pp. 87-101.

Shearer, J. T. and Niels, R.J.E. (1983): Carolin Mines: A geological Update, *Western Miner*, November 1983, pp. 21-24.

ELEMENT ZONING ASSOCIATED WITH GOLD MINERALIZATION AT CAROLIN MINE
(92H/11)

By G. E. Ray
Ministry of Energy, Mines and Petroleum Resources
and
R.J.E. Niels
Carolin Mines Ltd.

INTRODUCTION

The Carolin mine gold deposit lies about 20 kilometres northeast of Hope in southwestern British Columbia. When production started in 1982 reserves were estimated at 1.5 million tonnes grading 4.8 grams gold per tonne, at a cutoff grade of 2.7 grams gold per tonne.

This report summarizes findings of a geochemical study of 50 core samples that were collected from two drill holes totalling 130 metres in length which crosscut a portion of the Carolin mine deposit (Fig. 43). These were analysed for both major and trace element contents to define any correlatable patterns of element zoning, and to determine whether broader halos of element enrichment or depletion are present. Drill hole IU-49, which is 35 metres in length, crosscuts a 9-metre-wide, gold-bearing, sulphide-rich horizon in the upper part of the orebody (Fig. 43). By contrast, drill hole IU-53 partially intersects another thicker but folded ore zone and extends 60 metres beyond the mineralization (Fig. 43).

MINE GEOLOGY

The Carolin mine gold deposit (the Idaho zone), is hosted in Jurassic metasedimentary rocks of the Ladner Group, close to both their unconformable contact with Early Triassic (?) greenstones and their faulted contact with ultramafic rocks of the Coquihalla serpentine belt. The replacement-type, sulphide-albite-quartz mineralization is preferentially hosted in wackes, lithic wackes, and, to a lesser extent, siltstones; thin slaty argillite units in the mine sequence are generally unmineralized (Ray, *et al.*, 1983). Underground mapping shows the complex orebodies are structurally and stratigraphically controlled (Shearer and Niels, 1983), being largely confined to favourable lithological horizons within the hinge portion of a major, asymmetric antiform. However, it is uncertain whether the mineralization preceded, accompanied, or followed the folding. The ore zones are characterized by a visual increase in both sulphides and multiphase quartz veining (Figs. 44 to 47), although not all horizons carrying these minerals are enriched in gold. Sulphides in the deposit average 6 to 8 per cent by volume (Shearer and Niels, 1983) and mainly

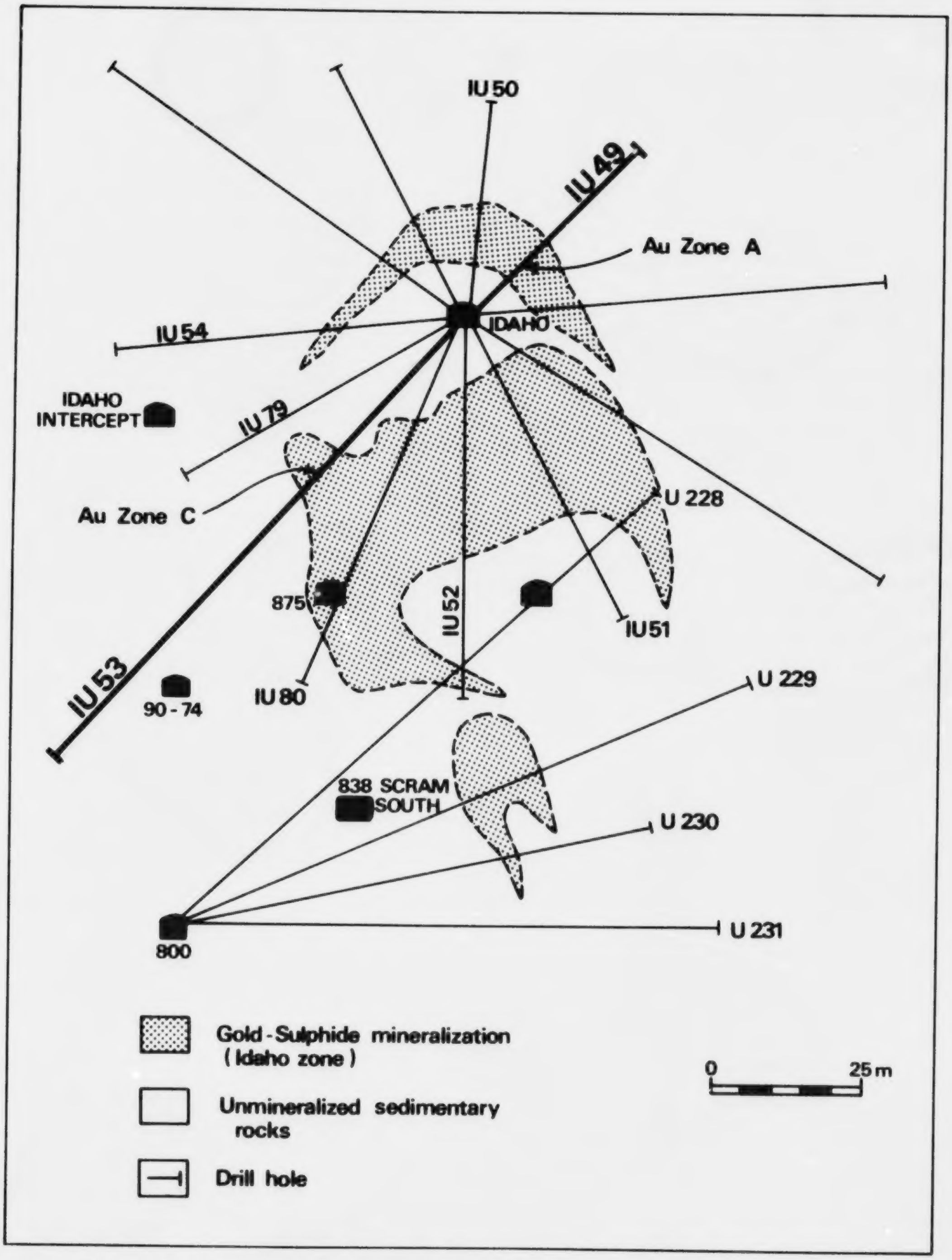

IU 50
IU 49
Au Zone A
IDAHO
IU 54
IDAHO INTERCEPT
IU 79
Au Zone C
U 228
875
IU 52
IU 51
IU 53
90-74
IU 80
U 229
838 SCRAM SOUTH
U 230
800
U 231
Gold-Sulphide mineralization (Idaho zone)
Unmineralized sedimentary rocks
Drill hole
0
25 m

Figure 43. Longitudinal cross-section through the Idaho zone-837 North - showing location of drill holes IU-49 and IU-53 (adapted from data supplied courtesy of Carolin Mines Ltd.).

comprise pyrrhotite, arsenopyrite, pyrite, and magnetite. Less common metallic minerals, in decreasing abundance, include chalcopyrite, bornite, and gold (Kayira, 1975).

GEOLOGY AND GEOCHEMISTRY OF HOLES IU-49 and IU-53

The two drill holes intersect an interbedded sequence of finely bedded siltstone, and poorly bedded to massive wacke and lithic wacke (Figs. 44 to 47). The latter contains angular to subrounded, generally volcanic clasts up to 1 centimetre in diameter; individual lithological units in the drilled sequence vary from 1 metre to over 20 metres in thickness. Complex network veins of white quartz up to 3 centimetres thick, together with disseminations and veins of sulphides, are concentrated preferentially in some coarse-grained wacke and lithic wacke units. However, veins and clots of albite show no spatial association with the sulphide-rich zones, but are widespread and common throughout the two drill holes.

Four sulphide-rich, auriferous horizons are intersected in the two drill holes; a single 9-metre-wide zone in IU-49, while IU-53 intersected a narrow upper horizon, an 11-metre-thick middle unit, and a narrow lower zone. These are designated auriferous zones A, B, C, and D respectively (Figs. 44 to 47). Hole IU-49 passes through zone A (Fig. 43), but IU-53 only partially intersects the hinge portion of a folded orebody (zone C); thus it lies entirely within a repeated hangingwall sequence (Fig. 43). Consequently, the narrow mineralized units B and D may represent the same folded auriferous horizon, although their dissimilar geochemistry makes this unlikely.

Trace and major element geochemical plots for the two drill holes are shown on Figures 44 to 47. It must be noted that these are quantitative values and no allowance has been made for any volume changes, as described by Gresens (1967). In addition to the elements shown, analyses also were completed for Cu, Hg, P_2O_5, and SrO. While Cu was very weakly, but sporadically anomalous (up to 310 ppm Cu) in some mineralized horizons, the other three elements showed no anomalous values throughout the drill holes.

Ore zone A contains markedly higher gold values adjacent to its footwall and hangingwall sections, and a clear correlation between gold and silver is apparent (Fig. 44). Mineralization in this horizon is also associated with anomalous values of Mo, Sb, and As - the latter reflecting the presence of arsenopyrite. However, these three elements are concentrated preferentially in the hangingwall of zone A, while Mo, for example, is absent in the footwall. By contrast, none of the three auriferous zones intersected in IU-53 contain anomalous quantities of Ag or Mo.

Auriferous horizons A, B, and C are associated with wide barium depletion zones (Figs. 44 and 46). The barium is presumably associated with potassium feldspar, since depletion coincides with a drop in the

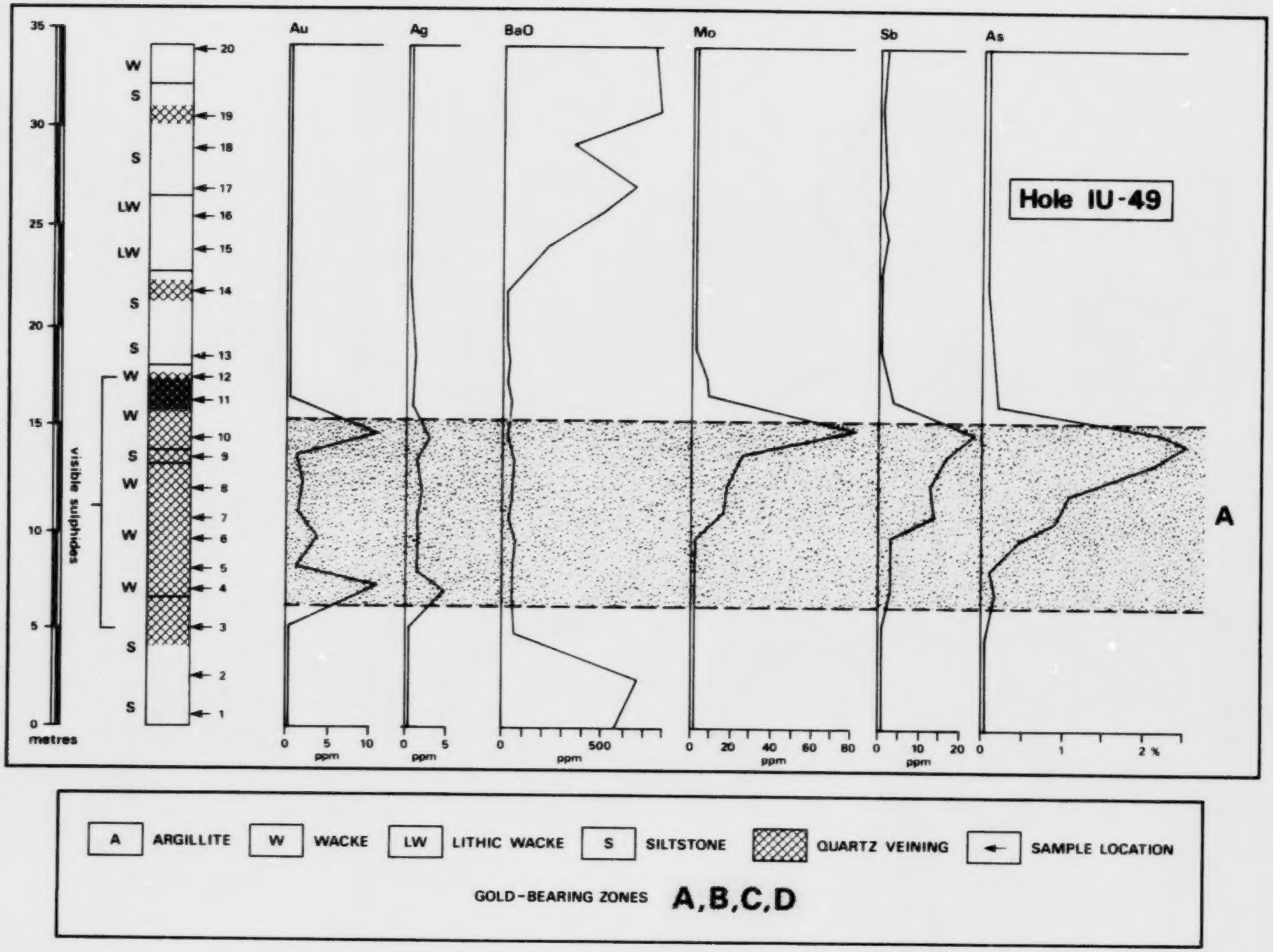


Figure 44. Geology and trace element geochemistry of hole IU-49, Carolin mine.

potassium content (Figs. 45 and 47). As expected, the sulphide-rich zones in both holes are associated with a decrease in water content (H_2O+) and an increase in sulphur. Surprisingly, the total iron and titanium values drop in parts of zones A, B, and C. This is particularly noticeable adjacent to the hangingwalls of zones A and C where it reflects both the presence of arsenopyrite and the effects of dilution caused by an increase in silica and quartz veining. Silica and CaO generally correlate negatively throughout both holes; SiO_2 values increase sharply in the hangingwall portions of zones A and C, where quartz veining is abundant, but drops off in the footwall sections. These SiO_2-enriched areas lie adjacent to narrow SiO_2 depletion zones situated in the country rock immediately above the hangingwalls of zones A and C. The MgO content decreases in the ore horizons, particularly in the hangingwall sections of zones A and C, but increases immediately above these auriferous horizons.

Compared to unmineralized Ladner Group siltstones and wackes outside the mine area, which average less than 4 per cent Na_2O, the entire 130-metre-long section of both IU-49 and IU-53 is anomalously enriched in sodium. Despite this, the relationship between mineralization and the sodium content is variable. Sodium levels rise moderately in parts of auriferous zones A and C, but drop in zones B and D. A narrow sodium depletion halo exists within, and immediately above, the hangingwall portion of zones A, C, and D (Figs. 45 and 47).

The relationship and distribution of elements within and adjacent to the gold-bearing zones A, B, and C show many common characteristics. By contrast, the lowermost auriferous zone D is geochemically unique; it is associated with a sharp drop in SiO_2 values, despite visible quartz veining, and with increases in CaO, total Fe, and TiO_2 (Fig. 47). Also, this zone is not associated with either barium or potassium depletion; instead the gold mineralization is marked by an increase in these two elements (Figs. 46 and 45).

CONCLUSIONS

Specific auriferous horizons at Carolin mine have complex and variable major and trace element zoning patterns in which gold is sometimes, but not always, associated with anomalous amounts of either Ag, Mo, As, or Sb. Most dramatic element changes generally occur within and immediately above the hangingwall sections of the ore horizons. The unique geochemical character of auriferous zone D, compared to zones A, B, and C, suggests that the Carolin mine orebody contains two mineralogically distinct ore suites.

The Carolin mine gold deposit is surrounded by a wide, sodium-enriched envelope that extends at least 60 metres beyond the mineralization. The lateral extent of this envelope is unknown and a program should be undertaken to establish its true dimensions. Lithogeochemical sampling

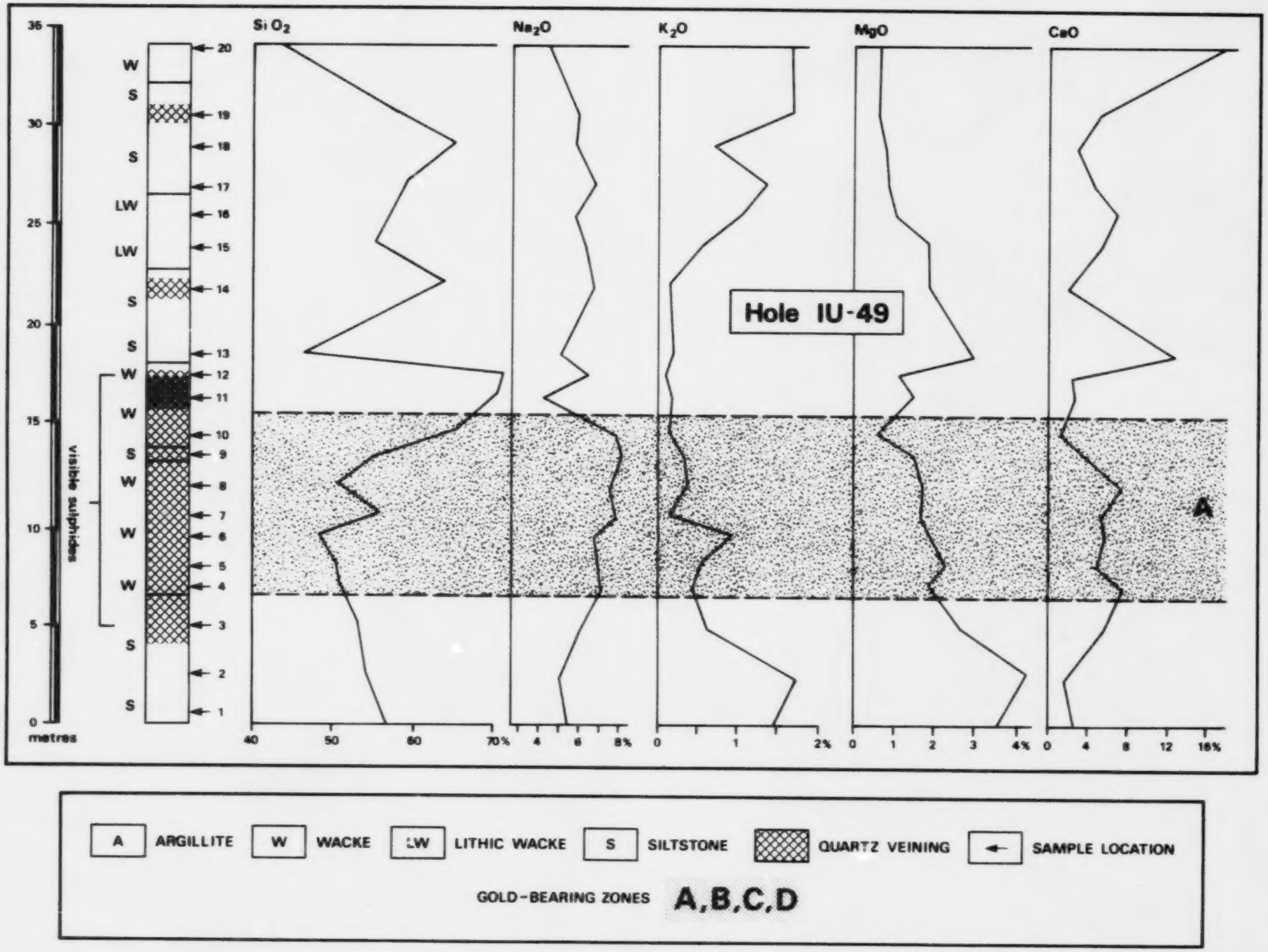


Figure 45. Geology and major element geochemistry of hole IU-49, Carolin mine.

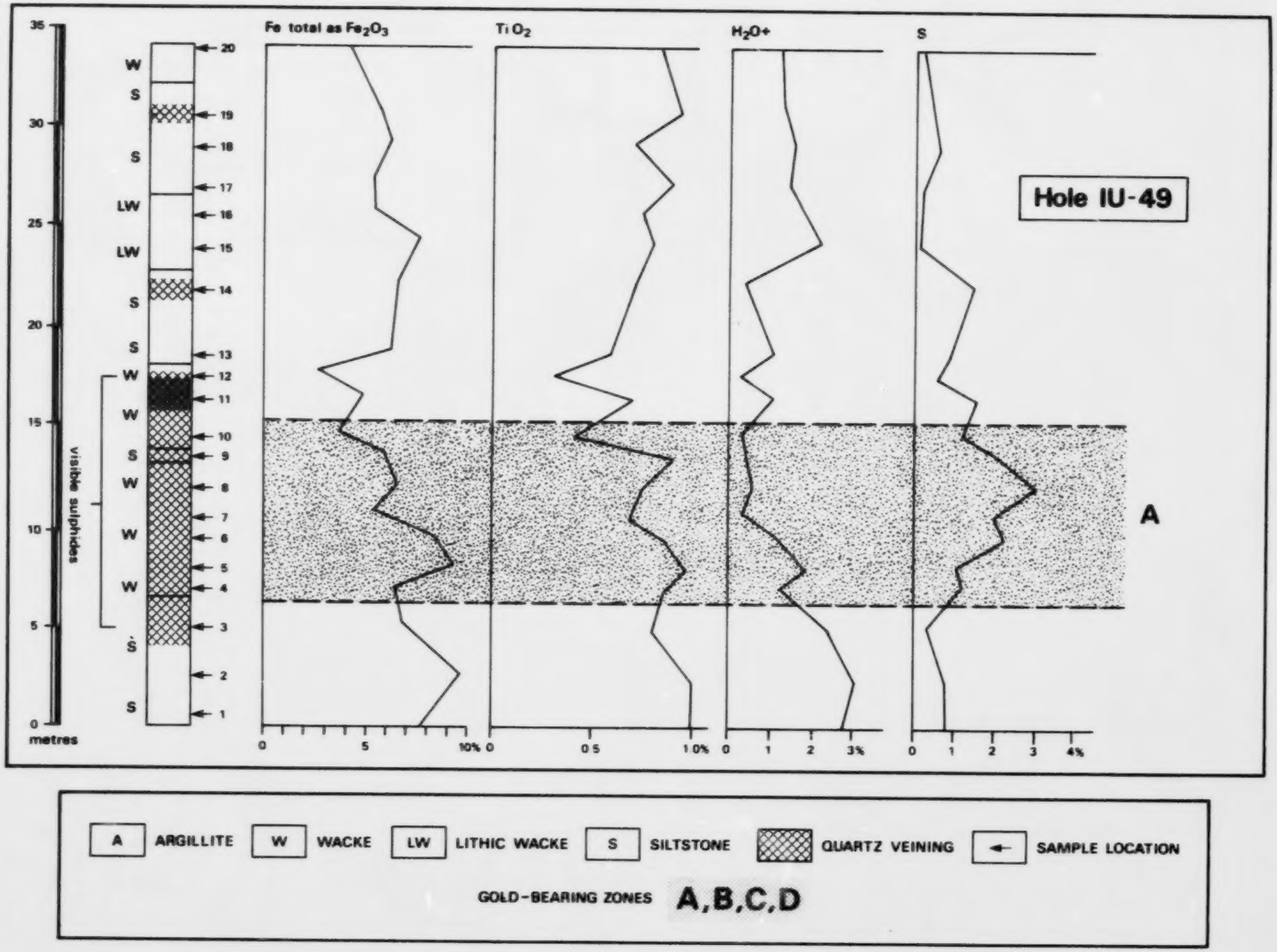


Figure 45. Geology and major element geochemistry of hole IU-49, Carolin mine.

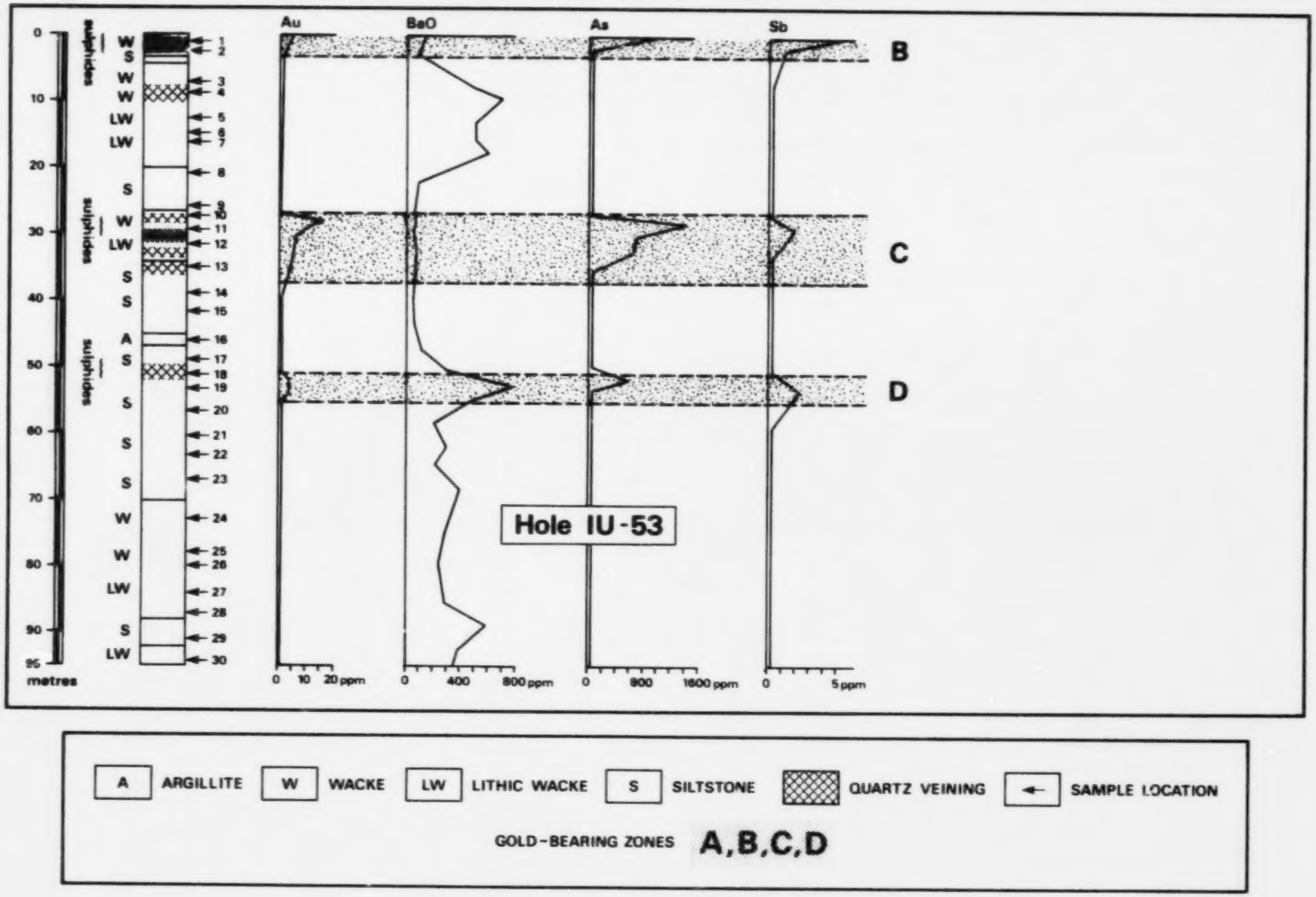


Figure 46. Geology and trace element geochemistry of hole IU-53, Carolin Mine.

to outline other areas of sodium enrichment probably represents a viable exploration tool for locating similar gold deposits in the district. Likewise, the barium and potassium depletion zones form valuable exploration drill targets since they are generally twice as wide as their associated gold-bearing horizons. Consequently, future underground drilling programs to locate extensions of the ore zones at Carolin mine should include routine barium or potassium analysis to test for any depletion in these elements.

ACKNOWLEDGMENTS

The authors wish to thank the management and staff of Carolin Mines Ltd. for their cooperation and permission to publish this data. Thanks are also expressed to A. J. Macdonald of the Ontario Geological Survey and J. T. Shearer of Trader Resources Ltd. for useful discussions, and to the staff of the Ministry of Energy, Mines and Petroleum Resources' laboratory for analytical work.

REFERENCES

Gresens, R. L. (1967): Composition-volume Relationships of Metasomatism, *Chem. Geology*, Vol. 2, pp. 47-65.

Kayira, G. K. (1975): A Mineralographic and Petrographic Study of the Gold Deposit of the Upper Idaho Zone, Hope, British Columbia, unpub. B.Sc. thesis, *Univ. of British Columbia*.

Ray, G. E., Shearer, J. T., and Niels, R.J.E. (1983): Carolin Gold Mine, *in* Some Gold Deposits in the Western Canadian Cordillera, *GAC-MAC-CGU*, Field Trip Guidebook No. 4, pp. 40-64.

Shearer, J. T. and Niels, R.J.E. (1983): Carolin Mines: A Geological Update, *Western Miner*, November 1983, pp. 21-24.

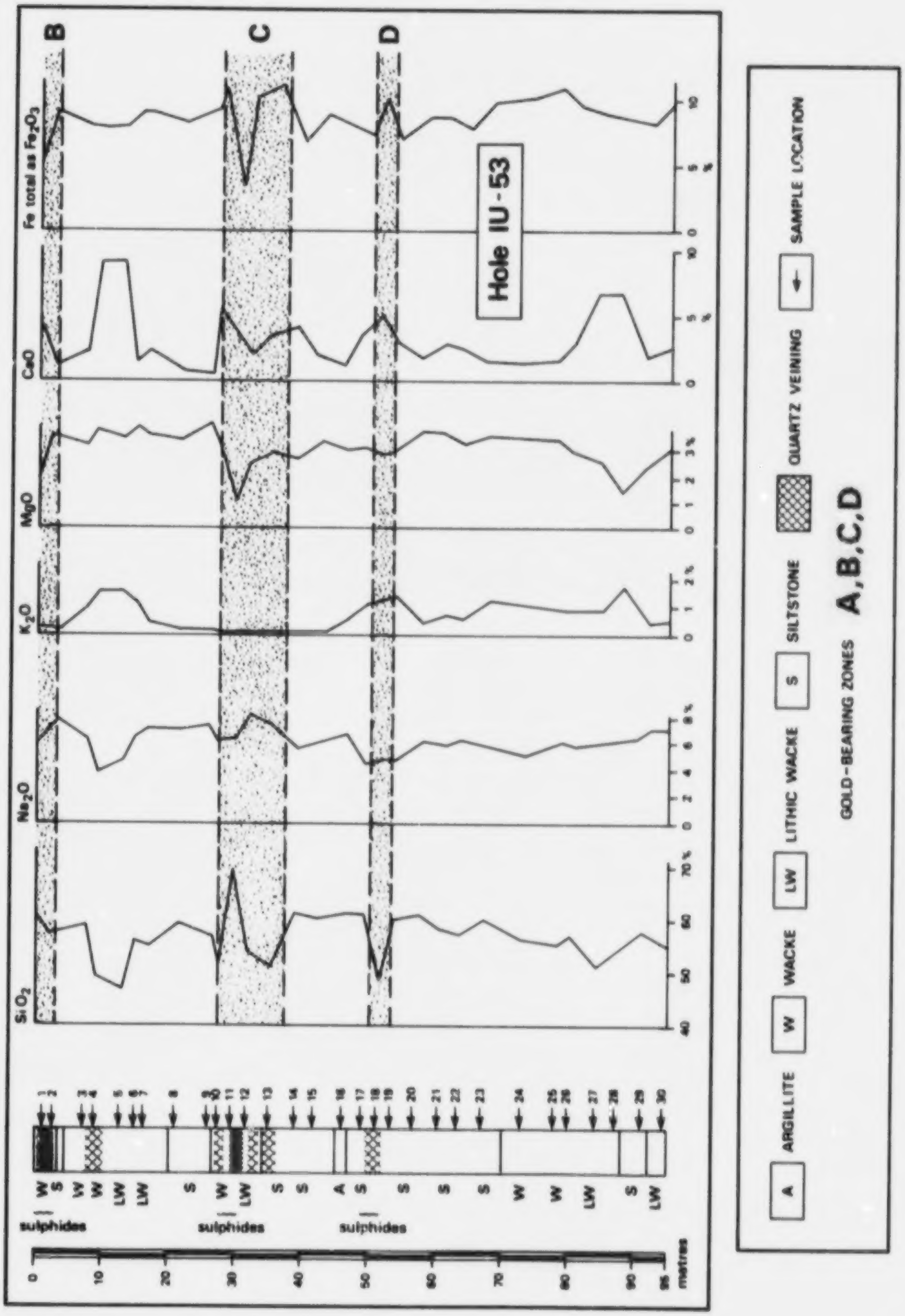


Figure 47. Geology and major element geochemistry of hole IU-53, Carolin mine.

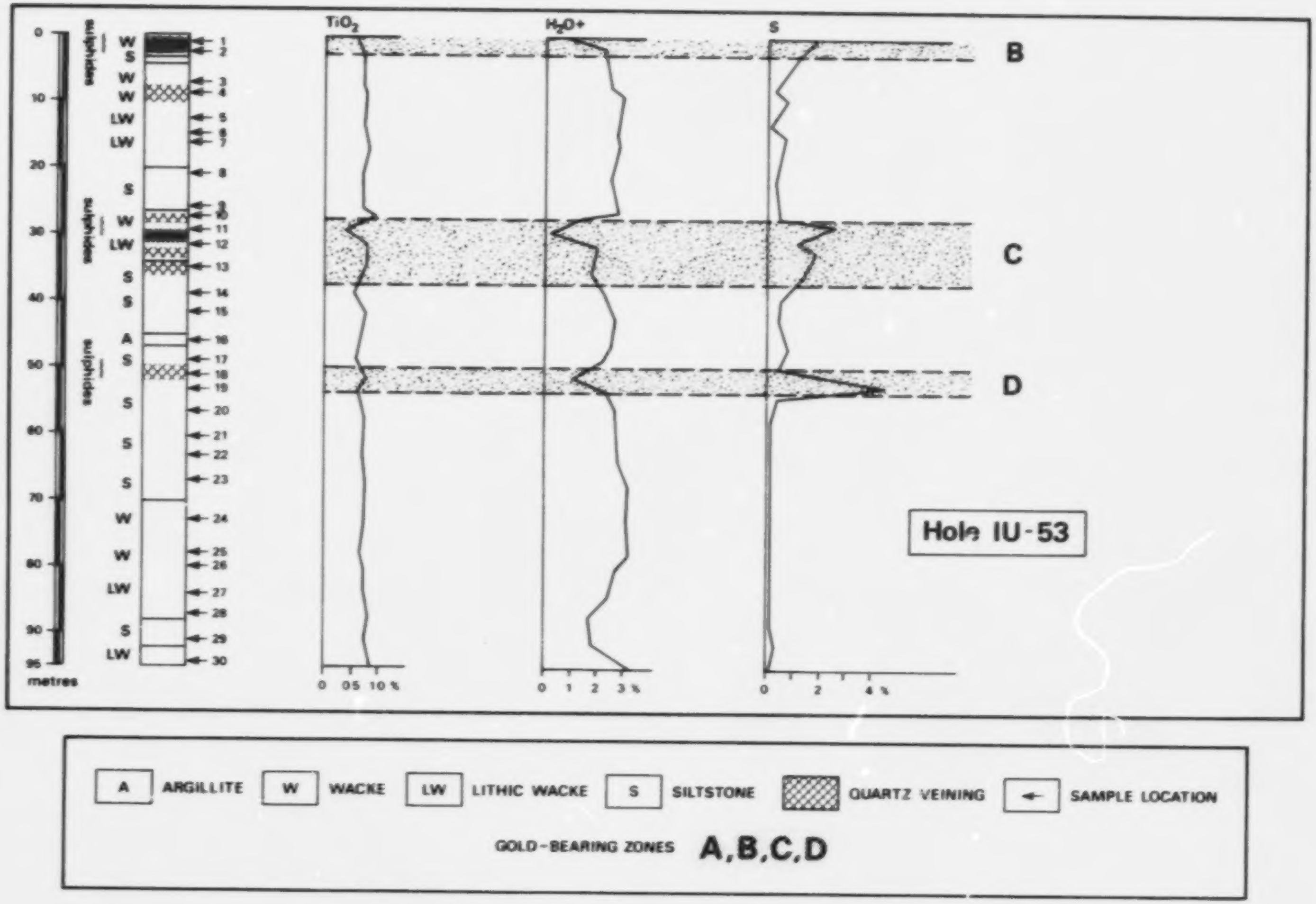


Figure 47. Geology and major element geochemistry of hole IU-53, Carolin mine.

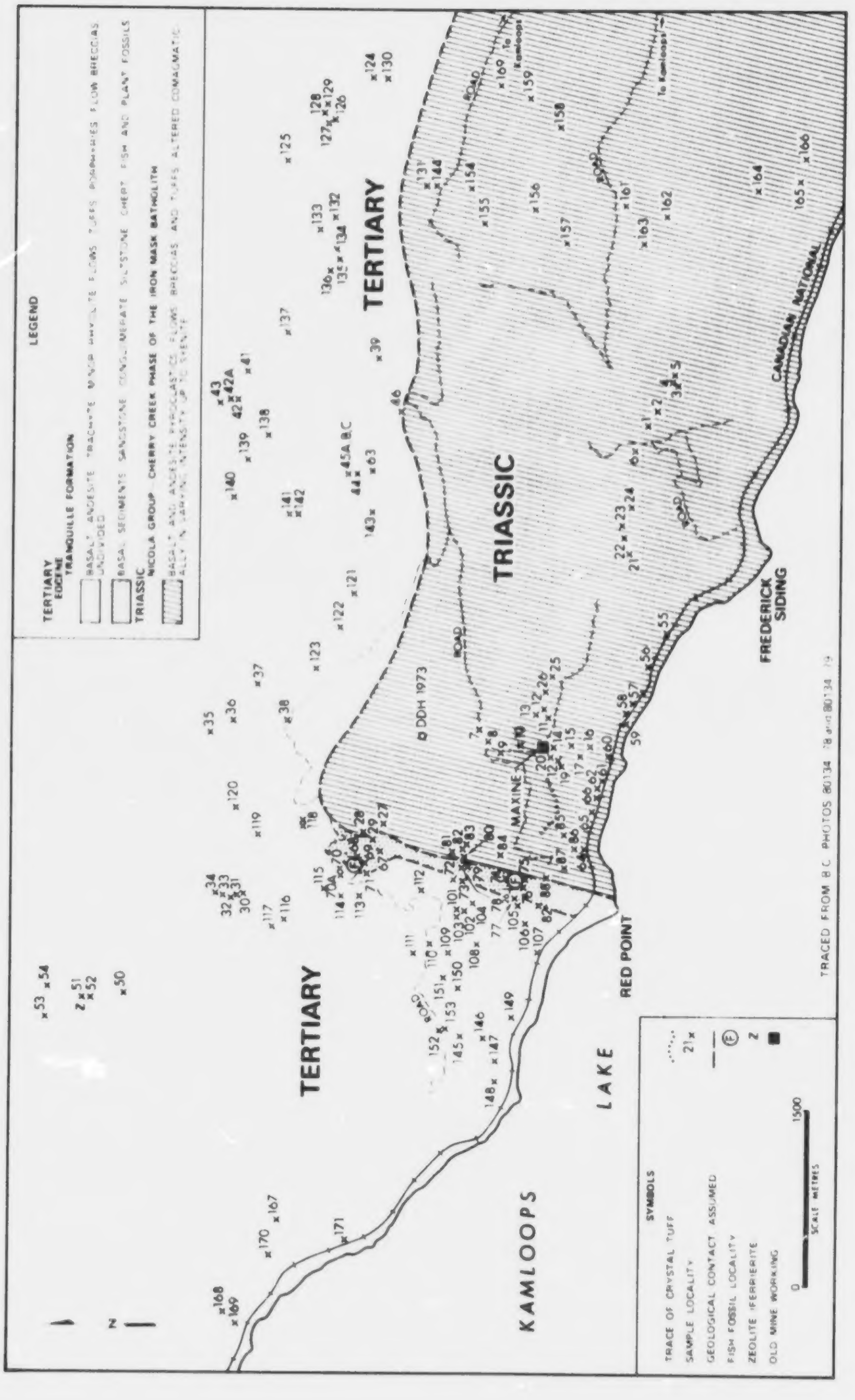

LEGEND
TERTIARY
EOCENE
TRANQUILLE FORMATION
BASALT, ANDESITE, TRACHYTE, MINOR RHYOLITE FLOWS, TUFFS, PORPHYRIES, FLOW BRECCIAS UNDIVIDED
BASAL SEDIMENTS: SANDSTONE, CONGLOMERATE, SILTSTONE, CHERT, FISH AND PLANT FOSSILS
TRIASSIC
NICOLA GROUP - CHERRY CREEK PHASE OF THE IRON MASK BATHOLITH
BASALT AND ANDESITE PYROCLASTICS, FLOWS, BRECCIAS AND TUFFS ALTERED COMAGMATICALLY IN VARYING INTENSITY UP TO SYENITE
SYMBOLS
TRACE OF CRYSTAL TUFF
SAMPLE LOCALITY
GEOLOGICAL CONTACT ASSUMED
FISH FOSSIL LOCALITY
ZEOLITE (FERRIERITE)
OLD MINE WORKING
0
1500
SCALE METRES
N
TERTIARY
TRIASSIC
KAMLOOPS
LAKE
RED POINT
FREDERICK SIDING
CANADIAN NATIONAL
MAXINE
DDH 1973
ROAD
To Kamloops
TRACED FROM B.C. PHOTOS BC134 78 and BC134 79

Figure 48. Plan map showing sample locations, North Kamloops Lake study area.

TERTIARY/TRIASSIC LITHOGEOCHEMICAL STUDY
NORTH KAMLOOPS LAKE AREA
(92I/10, 15)

By M. Mihalynuk
Department of Geology and Geophysics, University of Calgary
and
G.P.E. White
Ministry of Energy, Mines and Petroleum Resources

INTRODUCTION

During 1973 a hole was diamond drilled approximately 2.4 kilometres northwest of Red Point as indicated on Figure 48. The hole is reported to have intersected 1.6 per cent copper from 151 to 157 metres. A program of mapping and lithogeochemistry was carried out with two objectives in mind: (1) to discover potential copper abundances in the overlying Tranquille Formation derived from a possible underlying metallic sulphide deposit in the Nicola Group, and (2) to analyse for gold, silver, mercury, and arsenic to discover anomalies in the Tranquille that might lead to discovery of a precious metal deposit.

Rock samples were analysed at the British Columbia Ministry of Energy, Mines and Petroleum Resources' laboratory and the results are tabulated in Tables 1 and 2 (pages 154 to 157). For geochemical comparison purposes the Triassic to Lower Jurassic rocks have been placed in one group (Table 1) and the Eocene rocks in another. Nicola Group volcanic breccias, flows, and tuffs of andesitic to basaltic composition are recognizable in the field. Although the intensity of both epidote, calcite, hematite, chlorite alteration, and orthoclase feldspar metasomatism varies from outcrop to outcrop, copper values seem to be higher in the more altered rocks. Results for Eocene rocks of the Tranquille Formation are listed in Table 2.

North of Red Point, samples MM 82-76, 77, 78, and 79 are included with Triassic rocks based on the geochemical data; they are believed to be transported Nicola volcaniclastic rocks.

ANALYTICAL METHODS

Atomic absorption was used to analyse for gold (MM series only), silver, arsenic, and mercury. Gold for the GW series has a different gold detection limit than the MM series because GW samples were analysed by the gravimetric method. Gold values for MM samples are expressed in ppb while GW samples are in ppm.

GEOLOGY

INTRODUCTION

The area is underlain by Upper Triassic to Lower Jurassic Nicola volcanic and Iron Mask intrusive rocks, unconformably overlain by Eocene sedimentary and volcanic rocks of the Tranquille Formation.

Topographic changes are moderate, except for deeply incised stream valleys which give rise to cliffs in excess of 100 metres high.

In the following sections, numbers in parenthesis refer to outcrop sites on the plan (Fig. 48).

TRIASSIC

The Nicola Group consists of flows, flow breccias, tuff breccias, lapilli tuffs, and, locally, finely laminated tuffs that are brown-maroon in colour if altered to hematite or green if altered to epidote-chlorite; all are of andesitic to basaltic composition. The crystal tuffs form outcrops northeast of Red Point (20) and generally can be traced in the field. Flows and flow breccias are often porphyritic with ophitic to subophitic texture due to closely spaced euhedral to subhedral, fine to medium-grained plagioclase grains in an epidotized and chloritized, green matrix. A basalt dyke of possible Tertiary age was noted near the railway line northeast of Red Point (86); it intrudes a basalt flow. A lahar-like bed (18) containing polylithic, rounded clasts up to 15 centimetres in diameter is present below a waterfall south of the old Maxine mine workings and just south of the crystal tuff outcrop (20). The number of marker horizons are insufficient to estimate stratigraphic thicknesses of the Nicola Group.

The entire Nicola Group volcanic intrusive sequence has been subjected to pervasive epidote, chlorite, carbonate, and orthoclase feldspar alteration which abruptly varies in intensity from place to place. The most intense alteration was observed near Frederick siding. Although the original character is, for the most part, still apparent, Nicola rocks are on occasion changed to brick red syenite. The stronger alteration is commonly accompanied by copper mineralization.

The contact between Triassic and Tertiary rocks was not found. It is possible that a few large (10 by 20-metre) transported blocks of Triassic are present within Tertiary rocks above Red Point (75 and 77).

TERTIARY

The Tranquille Formation in this area consists of a basal sedimentary unit overlain by a sequence of volcanic rocks of basic to intermediate composition. Basalt and andesite dykes with a general northwesterly strike crosscut both the volcanic and sedimentary units.

The basal sedimentary unit is at least 40 metres thick and consists of sandstone, siltstone, mudstone, chert, and minor amounts of conglomerate. Grey to greyish white tephra layers are present in this unit north of Red Point; fish fossils were found at sites (69 and 76) in a fissile arkosic sandstone; plant fossils and coaly fragments are common in this thinly bedded, basal section. Olivine basalt and augite porphyries in 15-metre-thick layers that contain 4-metre-long pillows with discontinuous, interpillow sandstone wedge occur with the sedimentary beds west of the study area.

Volcanic rocks overlying the basal sedimentary unit consist of augite porphyry, olivine basalt, augite porphyry, breccia, pillowed basalt, pillow basalt breccia, andesite breccia, and basalt and andesite flows, as well as trachyte porphyry, flows, ash flows and dykes, and rhyolite ignimbrite. Bentonite beds 7 metres in thickness and derived from basaltic glass are interlayered with the basalt flows.

Basalt and andesite dykes that cut the sedimentary and volcanic rocks measure up to 10 metres in width, strike 120 degrees, and are nearly vertical.

A new location (51) of the zeolite ferrierite is shown on Figure 48. The identity of this rare mineral was recognized in the field and later confirmed in the laboratory. Another better known ferrierite locality in this region is at mile 17.5 of the Canadian National Railway, west of the map-area.

DISCUSSION OF LITHOGEOCHEMICAL RESULTS

A series of histograms accompany this report (Figs. 49 to 54, pages 158 to 160). The mean value of copper for Triassic rocks is 70 ppm and is somewhat higher than the mean of 50 ppm for Tertiary rocks. The broad scattering of values in this distribution is a reflection of the degree of alteration and attendant copper mineralization of the Nicola/Iron Mask rocks. Tranquille rocks, in contrast, show a much more concentrated distribution of values reflecting a substantially lower degree of alteration.

Mean values for gold and mercury Nicola/Iron Mask rocks (35 and 37 ppb) and Tranquille rocks (27 and 31 ppb) are only marginally different suggesting that the distributions of these two metals have been less affected by alteration in the Nicola/Iron Mask suite.

ACKNOWLEDGMENTS

All analyses were carried out by the British Columbia Ministry of Energy, Mines and Petroleum Resources' laboratory in Victoria.

TABLE 1

UPPER TRIASSIC TO LOWER JURASSIC NICOLA GROUP AND IRON MASK, LITHOGEOCHEMICAL RESULTS

Sample No.	Rock Type	Au ppb	Ag ppm	Cu ppm	Hg ppb	As ppm
MM 82- 1	Andesite pyroclastic	39	0.3	45	33	
2	Syenite	65	0.3	124	140	
3	Andesite breccia	57	<0.3	39	35	
4	Silica/calcite vein	31	0.4	92	38	
5	Quartz monzonite	31	<0.3	34	<15	
6	Andesite pyroclastic	32	0.3	440	<15	
7	Andesite breccia	49	0.3	49	20	
8	Andesite breccia	57	0.3	51	31	
9	Andesite crystal tuff	33	0.3	62	48	
10	Andesite pyroclastic	51	0.3	132	<15	
11	Andesite breccia	28	<0.3	24	19	
12	Andesite flow	50	0.4	164	32	
13	Sheared altered rock	36	<0.3	72	97	
14	Altered volcanic breccia	20	0.3	25	21	
15	Andesite flow	20	<0.3	21	18	
16	Mineralized shear	247	0.7	3 700	282	
17	Andesite flow	25	<0.3	54	41	
18	Lahar (?)	36	0.3	35	19	
19	Basalt tuff	28	<0.3	37	37	
20	Fault gouge	52	0.5	480	43	
21	Basalt breccia	33	0.3	54	16	
22	Altered mineralized rock	sample missing				
23	Altered basalt breccia	166	0.4	59	161	
24	Altered basalt tuff	27	<0.3	280	27	
25	Basalt crystal tuff	<20	0.3	120	29	
26	Mineralized basalt breccia	24	117	6 600	1 300	
27	Andesite breccia	24	0.3	290	19	
28	Andesite breccia	33	<0.3	105	22	
55	Syenite	<20	<0.3	215	330	
56	Syenite	<20	0.3	51	82	
57	Syenite	<20	0.3	530	700	
58	Syenite	23	0.4	104	380	
59	Altered crystal tuff	<20	<0.3	215	185	
60	Altered crystal tuff	20	0.3	58	154	
61	Syenite	20	0.3	26	32	
62	Pyroclastic andesite	20	0.3	30	33	
63	Altered andesite breccia	20	0.3	41	53	
64	Basalt	40	0.3	37	66	
65	Syenite	30	0.3	280	32	
66	Altered basalt breccia	<20	0.3	230	91	
80	Syenite	22	0.3	42	18	
81	Augite porphyry dyke	20	0.3	57	-	
82	Fault zone	22	0.3	300	22	
83	Altered volcanic	26	<0.3	40	30	
84	Basalt flow	35	0.3	86	12	
85	Andesite tuff	<20	<0.3	70	10	
85A	Basalt at dyke contact	37	0.3	19	58	

TABLE 1 (continued)

Sample No.	Rock Type	Au ppb	Ag ppm	Cu ppm	Hg ppb	As ppm
MM 82-86	Basalt dyke	<20	0.3	52	35	
86B	Basalt flow	20	<0.3	86	14	
86C	Basalt flow clast	20	0.4	23	43	
87	Basalt tuff	<20	1.2	6 700	42	
87A	Basalt flow	20	<0.3	95	38	
88	Basalt tuff	20	0.3	44	74	
		Au ppm				
GW 131-82	K-feldspar porphyry	<0.3	<10	26	23	19
144	K-feldspar porphyry	<0.3	<10	43	<15	42
154	Porphyritic altered andesite	<0.3	<10	24	<15	8
155	Andesite breccia	<0.3	<10	37	<15	18
156	Basalt flow	<0.3	<10	41	16	7
157	Altererd basalt breccia K-feldspar	<0.3	<10	91	<15	5
158	Basalt breccia	<0.3	<10	58	20	4
159	Andesite flow	<0.3	<10	54	18	4
160	Andesite	<0.3	<10	49	<15	8
161	Altered flow breccia	<0.3	<10	52	15	8
162	K-feldspar-altered pyroclast	<0.3	<10	286	485	3
163	Basalt breccia	<0.3	<10	66	18	3
164	Trachytic flow	<0.3	<10	42	19	4
165	Basalt breccia	<0.3	<10	62	<15	3
166	K-feldspar-altered basalt	<0.3	<10	225	15	6

TABLE 2
EOCENE TRANQUILLE FORMATION, LITHOGEOCHEMICAL RESULTS

Sample No.	Rock Type	Au ppb	Ag ppm	Cu ppm	Hg ppb	As ppm
MM 82-29	Andesite breccia (Nicola ?)	25	10	48	16	
30	Trachyte flow	31	0.3	66	29	
31	Siltstone	32	<0.3	59	32	
32	Rhyolite tuff	<20	<0.3	53	33	
33	Tephra - light coloured	20	<0.3	41	20	
34	Trachyte dyke	20	<0.3	69	15	
35	Ash flow (?) - trachytic	20	<0.3	67	24	
36	Ignimbrite	25	<0.3	95	<15	
37	Trachyte flow	<20	0.3	38	<15	
38	Siltstone	<20	<0.3	58	57	
39	Pyroclastic andesite	<20	<0.3	45	<15	
40	Andesite breccia	<20	<0.3	45	<15	
41	Augite porphyry basalt	<20	<0.3	80	<15	
42	Trachyte porphyry	<20	<0.3	57	<15	

TABLE 2 (continued)

Sample No.	Rock Type	Au ppb	Ag ppm	Cu ppm	Hg ppb	As ppm
MM 82-43	Porphrytic basalt	<20	0.4	49	15	
44	Pyroclastic andesite	25	<0.3	28	<15	
45	Siltstone	<20	0.3	55	<15	
46	Pyroclastic andesite	<20	<0.3	38	58	
47	Andesite flow	<20	0.3	32	20	
48	Pillow basalt augite - porphyry	<20	0.3	37	15	
49	Interstitial siltstone to pillows	<20	0.7	25	66	
50	Siltstone	<20	<0.3	34	51	
52	Augite porphyritic breccia - basalt	30	<0.3	48	<15	
53	Pyroclastic andesite	<20	0.3	55	15	
54	Augite porphyry - basalt	<20	<0.3	66	20	
67	Andesite flow	21	<0.3	41	39	
68	Augite porphyry	<20	<0.3	47	16	
69	Shale	<20	<0.3	55	30	
69A	Tephra	29	<0.3	20	19	
70	Cherty siltstone	<20	<0.3	68	12	
70A	Trachyte (?) ash	<20	<0.3	68	15	
71	Siltstone	<20	0.3	68	17	
72	Andesite flow	<20	0.3	46	20	
73	Siltstone	<20	0.6	50	50	
74	Andesite breccia	44	0.5	51	65	
75	Basal Tertiary conglomerate	<20	0.4	34	16	
76	Nicola fragment (?) in Tertiary	<20	0.4	158	23	
77	Argillaceous siltstone	<20	<0.3	69	116	
77A	White tuff	<20	<0.3	28	70	
78	Altered Nicola (?)	<20	<0.3	205	37	
79	Altered Nicola (?) volcaniclastic	<20	<0.3	154	31	
		Au ppm				
GW 101-82	Altered grey volcanic breccia	<0.3	<10	59	85	1
102	Chert	<0.3	<10	89	64	5
103	Sandstone	<0.3	<10	70	134	2
104	Mudstone	<0.3	<10	54	13	2
105	Trachyte (?)	<0.3	<10	29	50	1
106	Basalt breccia	<0.3	<10	63	19	1
107	Sandstone	<0.3	<10	63	60	30
108	Dacite	<0.3	<10	73	49	2
109	Basalt flow	<0.3	<10	32	40	1
110	Sandstone	<0.3	<10	25	39	3
111	Basalt dyke	<0.3	<10	29	35	2
112	Basalt dyke	<0.3	<10	29	45	3
113	Basalt dyke	<0.3	<10	33	21	1
114	Augite porphyry	<0.3	<10	61	18	1
115	0.6 m quartz-ankerite (?) vein	<0.3	<10	1.69%	276	4

TABLE 2 (continued)

Sample No.	Rock Type	Au ppm	Ag ppm	Cu ppm	Hg ppb	As ppm
GW 116-82	Basalt dyke	<0.3	<10	70	40	2
117	Basalt dyke	<0.3	<10	56	17	1
118	Andesite breccia	<0.3	<10	52	25	9
119	Dacite breccia	<0.3	<10	55	25	3
120	Sandstone	<0.3	<10	36	18	2
121	Basalt breccia	<0.3	<10	52	28	2
122	Basalt breccia	<0.3	<10	62	28	2
123	Basalt breccia with ash flow	<0.3	<10	56	24	2
124	Porphyritic basalt	<0.3	<10	55	23	<1
125	Basalt breccia	<0.3	<10	51	25	2
126	Olivine basalt	<0.3	<10	61	23	3
127	Calcite vein	<0.3	<10	24	25	2
128	Sheared basalt	<0.3	<10	48	20	1
129	Arkosic sandstone	<0.3	<10	40	34	4
130	Porphyritic basalt	<0.3	<10	57	29	1
132	Augite porphyry	<0.3	<10	53	18	2
133	Olivine basalt	<0.3	<10	41	23	2
134	Basalt flow	<0.3	<10	56	18	2
135	Near-pillow basalt	<0.3	<10	51	22	1
136	Pillow basalt	<0.3	<10	48	24	2
137	Groundmass basalt	<0.3	<10	48	36	3
138	Basalt flow (?)	<0.3	<10	43	27	2
139	Trachyte (?) tuff	<0.3	10	32	27	3
140	Porphyritic basalt	<0.3	10	29	27	3
141	Basalt flow	<0.3	10	49	20	2
142	Basalt pillow bx	<0.3	10	58	24	1
143	Basalt pillox bx	<0.3	10	51	21	2
145	Porphyritic basalt	<0.3	10	58	<15	2
146	Sandstone	<0.3	10	44	15	2
147	Basalt sill	<0.3	10	38	54	2
148	Cherty sediment	<0.3	10	67	15	1
149	Columnar basalt	<0.3	10	28	16	3
150	Basalt	<0.3	10	32	21	1
151	Sandstone	<0.3	10	23	<15	2
152	Basalt dyke	<0.3	10	75	15	4
153	Phyllite	<0.3	10	32	15	4
167	Basalt breccia fragment	<0.3	10	65	22	2
168	Basalt breccia fragment	<0.3	10	61	<15	2
169	Augite porphyry	<0.3	10	51	15	2
170	Augite porphyry	<0.3	10	57	15	2
171	Basalt flow	<0.3	10	63	15	2

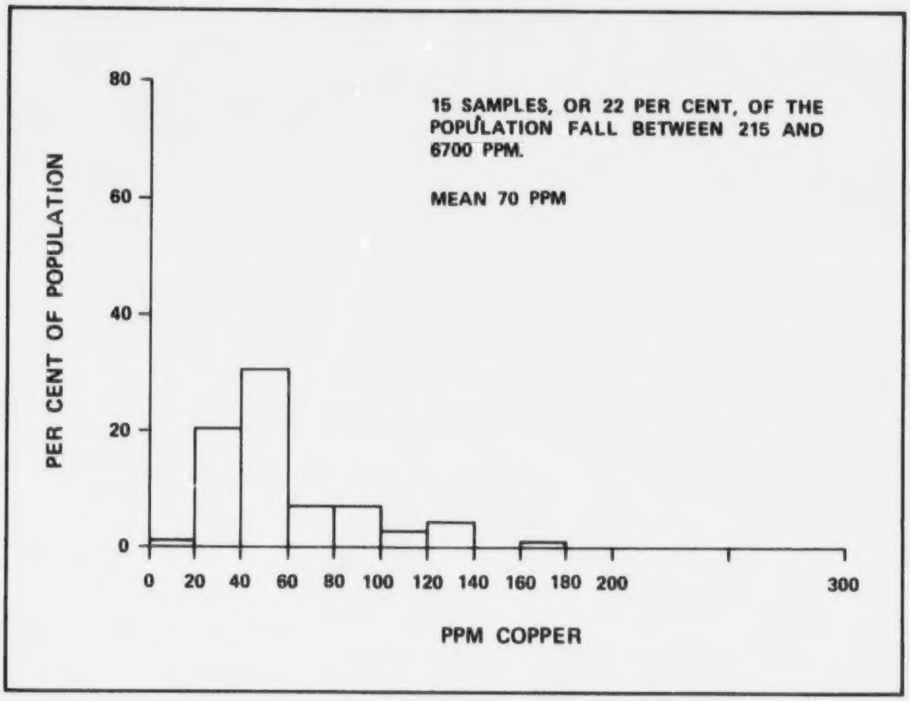


Figure 49. Histogram of copper in 68 Triassic Nicola/Iron Mask samples.

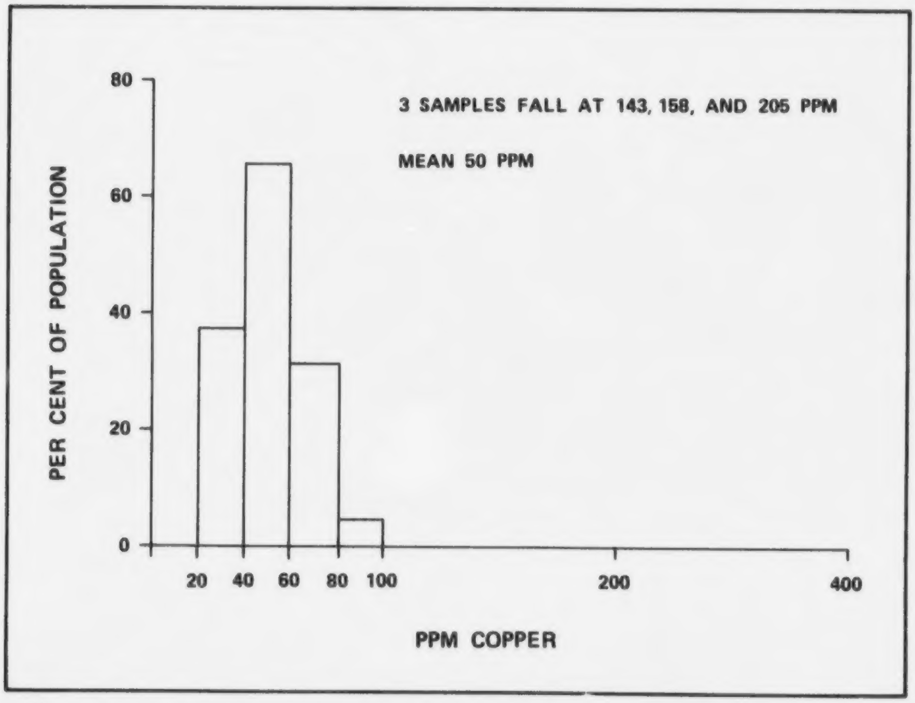


Figure 50. Histogram of copper in 67 Tertiary Tranquille Formation samples.

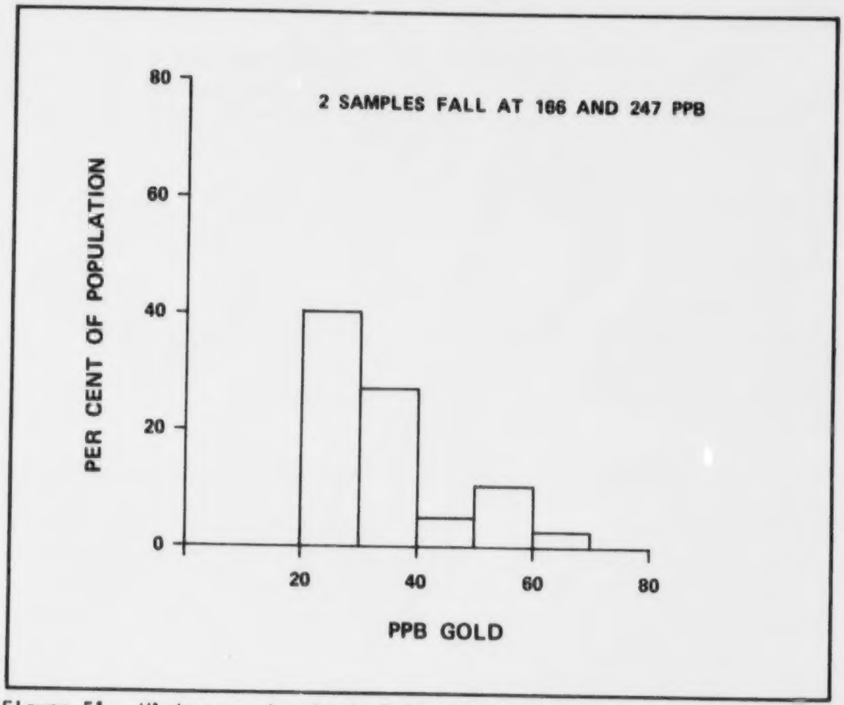


Figure 51. Histogram of gold in Triassic Nicola/Iron Mask samples. Only the 43 samples that exceeded the 20 ppb detection limit are plotted.

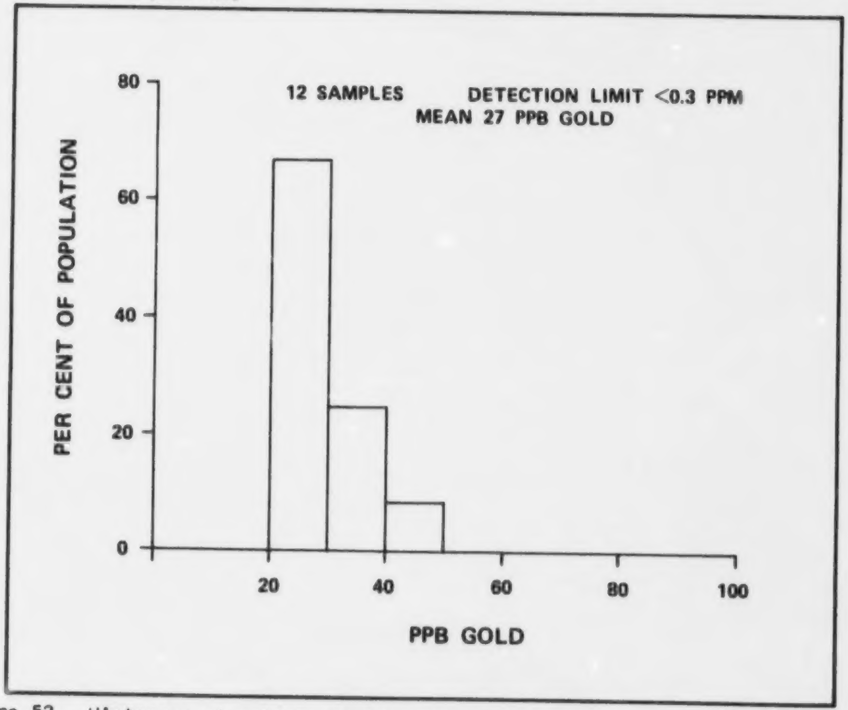


Figure 52. Histogram of gold in Tertiary Tranquille Formation samples. Only the 12 samples that have gold values above the 20 ppb detection limit are plotted.

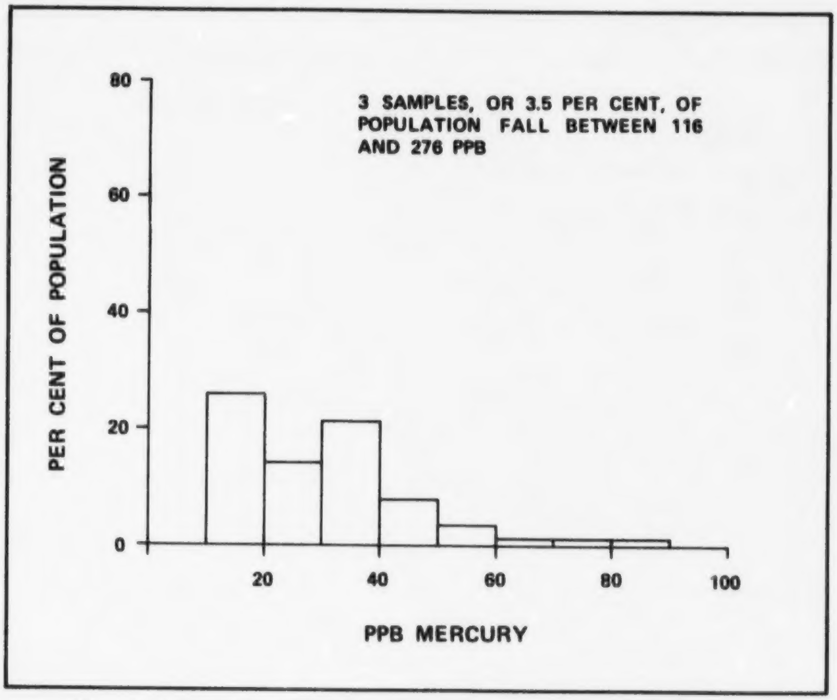


Figure 53. Histogram of mercury in Triassic Nicola/Iron Mask samples. The 57 samples in which Hg exceeded the 15 ppb detection limit are plotted.

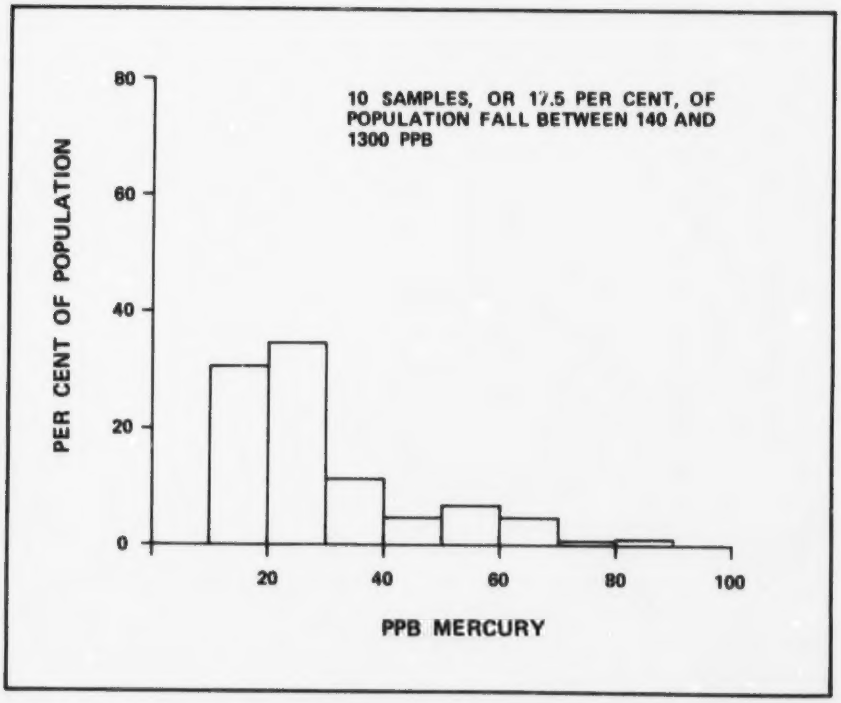


Figure 54. Histogram of mercury in Tertiary Tranquille Formation samples. The 85 samples in which Hg exceeded the 15 ppb detection limit are plotted.

GEOLOGY OF THE BROOKS PENINSULA, VANCOUVER ISLAND

(92L/4)

By W. R. Smyth

INTRODUCTION

A brief reconnaissance of the bedrock geology of the Brooks Peninsula, northern Vancouver Island, was made from August 8 to August 13, 1984. In addition, a stream sediment geochemical survey of most of the drainages on the Peninsula was completed. This work forms the basis of a mineral potential evaluation study of the area undertaken as part of the Ministry's commitment to resource evaluation required for land use planning.

The Ministry of Lands, Parks and Housing have proposed two areas on the north side of the Peninsula totalling 3 833 hectares as Ecological Reserves (Fig. 55). They wish to protect areas of biological importance, believed to have been glacial refugia. If the reserves are approved, the areas would be alienated from mineral exploration and development.

The area is isolated and remote with access limited to boat or aircraft. The two-man party was positioned at Columbia Cove by the Provincial Museum's 50-foot research vessel, the *Nesika,* in conjunction with a four-man party of paleocologists and biologists. The survey utilized a zodiac boat and limited helicopter traverses. It was only partially completed because poor weather forecasts caused the premature departure of the helicopter.

PREVIOUS WORK AND REGIONAL GEOLOGY

Muller published the first description of the geology of the Brooks Peninsula (Muller, *et al.*, 1974). He identified four major geological elements (Fig. 55); from northeast to southwest these are:

(1) *The Westcoast Fault.* A major fault that separates the Peninsula from Vancouver Island. The adjacent Vancouver Island area is underlain by a sequence of Triassic and Jurassic volcanic and sedimentary rocks of the Vancouver and Bonanza Groups and granitic rocks of the Island Intrusions.

(2) *The Westcoast Complex.* A variously deformed and metamorphosed mixture of gabbroic, dioritic, and granitic rocks which underlies 95 per cent of the Peninsula.

(3) *The Cape Cook Fault.* A major northwest-trending structure that juxtaposes the Westcoast Complex and the outboard Pacific Rim Complex.

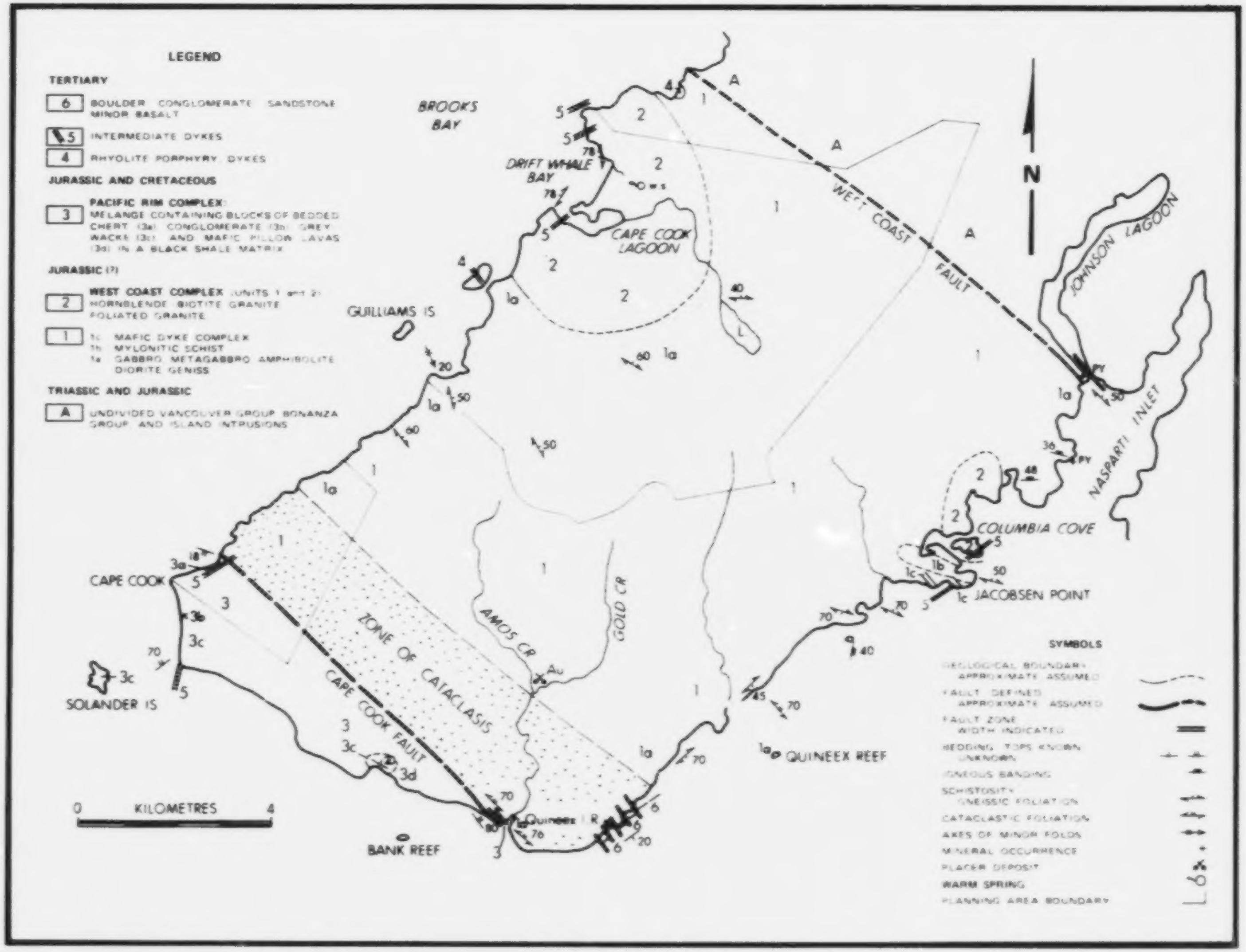

LEGEND
TERTIARY
6 BOULDER CONGLOMERATE SANDSTONE MINOR BASALT
5 INTERMEDIATE DYKES
4 RHYOLITE PORPHYRY DYKES
JURASSIC AND CRETACEOUS
3 PACIFIC RIM COMPLEX: MELANGE CONTAINING BLOCKS OF BEDDED CHERT (3a) CONGLOMERATE (3b) GREYWACKE (3c) AND MAFIC PILLOW LAVAS (3d) IN A BLACK SHALE MATRIX
JURASSIC (?)
2 WEST COAST COMPLEX (UNITS 1 and 2) HORNBLENDE BIOTITE GRANITE FOLIATED GRANITE
1 1c MAFIC DYKE COMPLEX
1b MYLONITIC SCHIST
1a GABBRO METAGABBRO AMPHIBOLITE DIORITE GENISS
TRIASSIC AND JURASSIC
A UNDIVIDED VANCOUVER GROUP BONANZA GROUP AND ISLAND INTRUSIONS
BROOKS BAY
DRIFT WHALE BAY
CAPE COOK LAGOON
GUILLIAMS IS
WEST COAST FAULT
N
JOHNSON LAGOON
NASPARTI INLET
COLUMBIA COVE
JACOBSEN POINT
QUINEEX REEF
ZONE OF CATACLASIS
CAPE COOK FAULT
AMOS CR
GOLD CR
Au
PY
CAPE COOK
SOLANDER IS
BANK REEF
Quineex I.R.
0 KILOMETRES 4
SYMBOLS
GEOLOGICAL BOUNDARY APPROXIMATE ASSUMED
FAULT DEFINED APPROXIMATE ASSUMED
FAULT ZONE WIDTH INDICATED
BEDDING TOPS KNOWN UNKNOWN
IGNEOUS BANDING
SCHISTOSITY GNEISSIC FOLIATION
CATACLASTIC FOLIATION
AXES OF MINOR FOLDS
MINERAL OCCURRENCE
PLACER DEPOSIT
WARM SPRING
PLANNING AREA BOUNDARY

Figure 55. Geological map, Brooks Peninsula, Vancouver Island.

(4) *The Pacific Rim Complex*. A melange unit that is confined to the outermost part of the Peninsula, but is more extensive than shown on Muller's map (1983).

A fifth element consisting of Tertiary conglomerates and sandstones crops out on the southwest edge of the Peninsula but is not shown on Muller's map (1983).

An area on the southeast corner of the Peninsula shown to be underlain Bonanza volcanic rocks by Muller (1983) is here interpreted to be underlain by the Westcoast Complex.

GENERAL GEOLOGY

WESTCOAST COMPLEX (UNITS 1 and 2)

Westcoast Crystalline Complex is a term proposed by Muller and Carson (1969) for a complex of amphibolite, basic migmatite, and gneissic quartz diorite and gabbro that outcrops on the west coast and in inlets in the Alberni map-area. Muller, *et al.* (1974) subsequently applied the name to similar rocks that outcrop on the Brooks Peninsula. Two main map units (units 1 and 2) were recognized in the complex in this study.

Unit 1 - Gabbro, Metagabbro, Mylonitic Schists, and Mafic Dykes

Unit 1 consists of the non-granitic rocks of the Westcoast Complex. It comprises three sub-units: 1a - an extensive unit of variably deformed and metamorphosed gabbro, 1b - mylonitic schists, and 1c - mafic dykes.

Sub-unit 1a - Gabbro, Metagabbro, Amphibolite Gneiss, and Migmatite

Undeformed to weakly deformed gabbro constitutes less than 10 per cent of this sub-unit. It is exposed mostly on the southeast side of the Peninsula, away from the Westcoast fault. A crude mineralogical banding defined by concentration of mafic minerals on a 3 to 5-centimetre scale is developed locally on the north shore of Nasparti Inlet. The banding is discontinuous over 2 metres and may be the result of magmatic flowage differentiation, not gravity settling.

In most places the unit consists of foliated gabbros and amphibolites. In zones of high strain they are converted to banded amphibolite gneiss, such as south of Guilliams Island. Migmatite and agmatite are locally developed adjacent to granitic intrusions, for example, south of Cape Cook Lagoon.

Sub-unit 1a is everywhere intruded by granitoid dykes and pegmatites and, in at least two localities, by granitoid intrusions (unit 2) up to 4 kilometres across. Foliated intrusion breccia with aligned zenoliths of gabbro is exposed at the northern contact of the Columbia Cove granite.

Sub-unit 1b - Mylonitic Schist

A narrow unit (approximately 350 metres) of banded mylonite outcrops at the southern entrance to Columbia Cove. The mylonite varies in composition from granitic to calc-silicate. Thin amphibolite bands are also present. Isolated, lensoid granitic fragments up to 50 centimetres across occur surrounded in calc-silicate schists. These superficially resemble a metaconglomerate but are more likely highly attenuated and flattened intrusion breccia.

The northern contact of the mylonitic schists is not exposed. The southern contact is obscured by a swarm of mafic dykes (sub-unit 1c) that cut the schists.

Sub-unit 1c - Dyke Complex

A narrow unit of fine-grained and porphyritic mafic dykes outcrops on the south shore of Jacobsen Point. The dykes are undeformed to mildly deformed in contrast to the schists that they intrude. They trend 160 degrees and are dark green, grey to black. Rare screens of medium-grained gabbro are present.

The mafic dykes are intruded by a Tertiary(?) dyke (unit 5), which provides an upper age limit for them.

Unit 2 - Granitoid Intrusions

Numerous granitic dykes, pegmatites, and two mappable granitoid intrusions cut sub-units 1a and 1b. The intrusions are informally referred to as the Columbia Cove granite and the Cape Cook Lagoon granite.

The Columbia Cove granite is medium and coarse-grained, hornblende-biotite granite. It is massive in the centre but toward the eastern contact with the gabbros a 25-metre-wide wide zone of intrusion breccia with a strong schistosity is developed.

The Cape Cook Lagoon granite is a deformed hornblende-biotite granite. It contains numerous aligned and flattened inclusions and screens of gabbro, diorite, and pyroxenite, indicating systectonic intrusion.

Locally, granitoid dykes are more deformed than the gabbro host rocks; they were probably intruded into active shear zones.

PACIFIC RIM COMPLEX (UNIT 3)

Muller, *et al.*, (1974) assigned the name Pacific Rim Complex to a highly disturbed and faulted sequence of argillite, greywacke, sandstone, and quartzite exposed near Cape Cook. The unit is in fact a melange containing exotic blocks or 'knockers' in a matrix of deformed black and green shale. Some of the knockers are so large (up to 50 metres) that they can be distinguished on a 1:50 000-scale map. The complex is much wider than shown by Muller (1983). It forms most of the southwest coast of the Peninsula, and the numerous rocks, reefs, and shoals that extend up to 1 kilometre offshore. Many of these features are isolated, resistant knockers, standing above the eroded shale matrix.

A tectonic slice or block containing bedded ribbon cherts (sub-unit 3a) is well exposed on the coast about 1 kilometre northeast of Cape Cook. The ribbon cherts occur in a sequence of greywacke, chert, breccia, and lesser black shale melange. No tops were determined. The cherts are up to 20 metres thick and are tightly and complexly folded. Individual ribbons are commonly 3 to 5 centimetres thick; they are separated by thin laminae of black argillite. The cherts are light green to grey and weather white.

This sequence is structually overlain to the northeast by black brecciated argillites (?) which lie adjacent to the Cape Cook fault.

The greywackes (sub-unit 3c), which outcrop adjacent to the ribbon cherts and as knockers throughout the melange, are fine grained, dark green to grey, massive, and indistinctly bedded. Small rip-up clasts of black shale are common. Greywackes also underlie Solander Island (C. Yorath, personal communication), which lies 2 kilometres southwest of Cape Cook.

Knockers consisting of bedded and graded cobble conglomerate and sandstone (sub-unit 3b) occur in the melange 2 kilometres south of Cape Cook. The clasts are subrounded and consist of sandstone, chert, black argillite, quartzite, gabbro, and granite. One large knocker 5 metres across contains a sequence of beds, each up to 1 metre thick, of sandstone, conglomerate, and black shale.

Blocks of mafic pillow lava (sub-unit 3d) occur in the melange on the shore north of Banks Reef. The pillows contain carbonate interpillow material.

The melange also contains a thin wedge of thinly laminated, dark grey, fine-grained, calcarcous siltstone toward the southern contact with the Cape Cook fault. The siltstones are extensively brecciated close to the fault.

RHYOLITE PORPHYRY AND DYKES (UNIT 4)

Two small, post-tectonic rhyolite porphyry intrusions cut the Westcoast Complex on the northwest coast of the Peninsula. The top of a porphyritic rhyolite intrusion, 5 metres across cuts deformed gabbro south of the Westcoast fault. The rhyolite is compositionally banded parallel to the domed contact. The rhyolite contains phenocrysts of quartz, K-feldspar, and biotite; it weathers white.

A 2-metre-wide, flow-banded porphyritic rhyolite dyke cuts migmatitic gneisses on a small island southwest of Cape Cook Lagoon. It is compositionally similar to the rhyolite intrusion.

The rhyolites postdate major deformation and faulting in the area and are believed to be of Tertiary age.

INTERMEDIATE DYKES (UNIT 5)

A number of northeast-trending, intermediate dykes cut both the Westcoast Crystalline Complex and the Pacific Rim Complex. These dykes are unaffected by the intense cataclasis associated with the Cape Cook fault and are assumed to be Tertiary in age. The dykes are dark grey, fine grained to porphyritic; locally they contain rounded quartz phenocrysts or amygdules.

BOULDER CONGLOMERATE, SANDSTONE, AND MINOR BASALT (UNIT 6)

A thin sequence of cobble to boulder conglomerate that passes upward into grits and sandstones unconformably overlies cataclastic gabbro of the Westcoast Crystalline Complex in the immediate vicinity of the Quineex Indian Reserve (locally known as Shelter Sheds).

The conglomerates are exposed at low tide level in a narrow graben (approximately 25 metres wide) that defines the Quineex canoe run as well as on islands and headlands 1 kilometre northeast and 0.5 kilometre southwest. The unit is undeformed and beds dip 20 degrees oceanward. Only about 50 metres of strata is exposed.

The unconformity surface is exposed in many places and has a relief up to 1 metre. Boulders of gabbro breccia up to 1 metre across occur on the unconformity surface. The conglomerate contains rounded cobbles and boulders of foliated gabbro, greenschist, granite, and cobbles and pebbles of rounded quartz.

A fine-grained, dark brown basalt flow or sill is interlayered with the basal conglomerate in the Quineex graben. The basalt is exposed at low tide and is at least 2 metres thick; the top is unexposed underwater. The basalt tongues into the underlying conglomerates and isolated conglomerate fragments are caught up in the basalt.

The conglomerate is tentatively correlated with the Eocene/Oligocene Escalante Formation, which occupies a similar lithostratigraphic position in the Nootka Sound map area 75 kilometres to the south (Muller, 1981). These outcrops on Brooks Peninsula are the most northerly known onshore exposures of this formation.

STRUCTURE

The Cape Cook fault is the major structure in the peninsula. It separates the Pacific Rim Complex and the Westcoast Crystalline Complex and trends northwesterly across the southwest tip of the Peninsula. The fault is exposed northwest of Amos Creek where it is marked by tectonically interleaved thin slices of limestone and chert, which are up to 50 centimetres thick, with brecciated gabbros. At this locality, sedimentary rocks of the Pacific Rim Complex dip steeply to the northwest under the Westcoast Complex and the gabbros of the Westcoast Complex are closely brecciated. Extensive brecciation of the gabbros continues for up to 3 kilometres away from the fault. The breccias consist of angular fragments of gabbro, generally from 3 to 10 centimetres across, in a comminuted groundmass; no veining was noted. This cataclasis is interpreted to have been caused by underthrusting of the Pacific Rim Complex under the Westcoast Complex.

The Westcoast fault also trends northwest and is exposed at the entrance to Johnson Lagoon. It is marked by a 700-metre-wide zone of mylonitized Island Intrusion granite. The mylonite dips moderately to the northwest. Brecciated and foliated gabbros and foliated greenschists of the Westcoast Complex are juxtaposed against the mylonite. The greenschists and the granitic mylonite are openly folded about northwest-trending axes.

The Westcoast fault was not observed on the north coast where it juxtaposes Westcoast Complex and mafic volcanic rocks of the Triassic Karmutsen Formation.

MINERALIZATION

Mylonites associated with the Westcoast fault at Johnson Lagoon contain thin stringers of pyrite. Assays did not reveal any anomalous gold or silver values.

Large, rusty, pyrite-bearing boulders of fine-grained granite were observed on the headland 1.5 kilometres southwest of Johnson Lagoon.

Disseminated pyrite occurs in volcanic rocks of the Karmutsen Formation 1.6 kilometres northeast of the Westcoast fault at Brooks Bay.

Coarse and fine-grained placer gold has been reported from near the junction of Amos and Gold Creeks (MINFILE 92L/248). This area was worked in the 1910's but there is no record of production. The assessment report (Neave, 1913) describing the work is unfortunately missing from the Ministry's files. The source of the placer gold has not been determined.

MINERAL POTENTIAL

The metallic mineral potential of the Westcoast Complex and the Pacific Rim Complex appears to be low. The Cape Cook fault shows no evidence of associated hydrothermal activity. The Westcoast fault contains some pyrite and probably deserves closer attention to evaluate its potential.

The small Tertiary rhyolite stock and dykes mapped on the north shore of the Peninsula line up with a belt of Tertiary volcanic rocks that trend northeast across Vancouver Island. This trend was named the Brooks Peninsula Fault Zone by Muller, *et al.* (1974). A warm spring, reported to exist at the source of a small stream that exits at the northeast corner of Drift Whale Bay, also lies on this trend. These data indicate probable Tertiary igneous activity in this area.

Tertiary volcanic and intrusive rocks are favourable metallotects elsewhere on Vancouver Island (Carson, 1969; Muller, *et al.*, 1974). Probably the greatest mineral potential of the Brooks Peninsula lies in discovering mineralized Tertiary igneous rocks in the unexplored interior of the Peninsula.

LAND USE RECOMMENDATION

A land use recommendation will not be made until the geochemical data is available. Any persons knowing of additional mineral occurrences on the Peninsula are requested to make this information available to the Ministry.

ACKNOWLEDGMENTS

Mr. Don Travers was a competent and cheerful field assistant, and a good boatman. Mr. Ross Brand, skipper of the *Nesika*, and his crew are thanked for their generous hospitality and transportation. Dr. Richard Hebda kindly invited us to join the expedition. He and his colleagues were a constant source of encouragement and good humour in the seemingly never ending rains. Dr. Bill McMillan kindly reviewed the manuscript and suggested many improvements.

REFERENCES

B.C. Ministry of Energy, Mines & Pet. Res.: MINFILE, File 92L, 1983.

Carson, D.J.T. (1969): Tertiary Mineral Deposits of Vancouver Island, British Columbia, *C.I.M.*, Bull., Vol. 72, pp. 116-125.

Muller, J. E. (1981): Geology, Nootka Sound, British Columbia, *Geol. Surv., Canada*, Map 1537A.

.... (1983): Geology, Alert Bay-Cape Scott, British Columbia, *Geol. Surv., Canada,* Map 1552A.

Muller, J. E. and Carson, D.J.T. (1969): Geology and Mineral Deposits of Alberni Map Area, British Columbia (92F), *Geol. Surv., Canada,* Paper 68-50.

Muller, J. E., Northcote, K. E., and Carlisle, D. (1974): Geology and Mineral Deposits of Alert-Cape Scott Map Area, British Columbia, *Geol. Surv., Canada,* Paper 74-8.

Neave, H. E. (1913): Auriferous Gravels - Brooks Peninsula, *B.C. Ministry of Energy, Mines & Pet. Res.,* private Assessment Report.

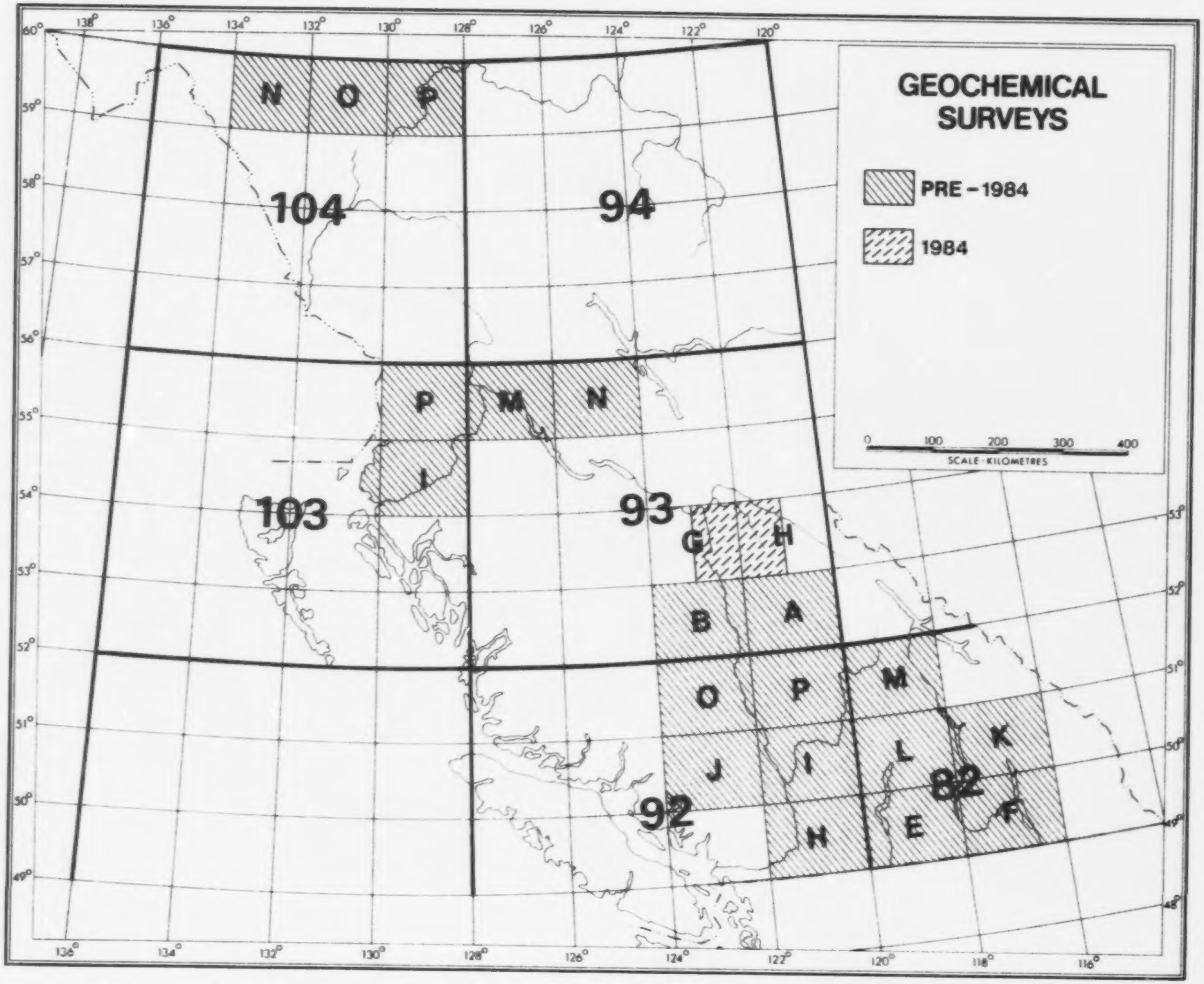

GEOCHEMICAL SURVEYS
▨ PRE-1984
▨ 1984
0
100
200
300
400
SCALE-KILOMETRES
104
94
103
93
92
82
N
O
P
P
M
N
I
G
H
B
A
O
P
M
J
I
L
K
H
E
F
60°
59°
58°
57°
56°
55°
54°
53°
52°
51°
50°
49°
48°
138°
136°
134°
132°
130°
128°
126°
124°
122°
120°
118°
116°

Figure 56. Location map for Regional Geochemical surveys carried out in British Columbia.

REGIONAL GEOCHEMICAL SURVEY 12
PRINCE GEORGE (EAST HALF) AND McBRIDE (WEST HALF)
(93G/E, 93H/W, 93H/2)

By H. R. Schmitt

The British Columbia Ministry of Energy, Mines and Petroleum Resources conducted a regional geochemical survey during July and August of 1984 which covered the eastern half of NTS 93G and the western half of 93H and included part of 93H/2 (Fig. 56).

The Ministry funded organization, supervision, and sample collection activities while the Department of Energy, Mines and Resources in Ottawa funded commercial sample preparation and analyses, and data processing. Field supervision was carried out by H. R. Schmitt under the direction of W. J. McMillan.

Survey results in the form of sample location and value maps, a listing of sample data, and a summary of basic statistical parameters will be released in June, 1985 in Prince George and/or Quesnel, Vancouver, and Victoria.

To date a total of 20 map-areas covering approximately 264 750 square kilometres have been sampled in British Columbia; average sample density ranges from one site per 12.5 square kilometres to one site per 15 square kilometres.

Field sampling for RGS 12 was carried out under contract by McElhanney Engineering Services Ltd. of Vancouver, with an average crew of five. Access is excellent through much of the survey area so most sample sites were accessed by truck and motorcycle. Base camps were situated at Quesnel, Hixon, Purden Lake, and Wells. Helicopter services were provided on a casual basis by Northern Mountain Helicopters Inc. of Quesnel and Prince George. The survey commenced on July 10, 1984 and concluded successfully on September 2, 1984.

A total of 1 167 sites were sampled, resulting in a mean site density of one site per 12.6 square kilometres over the 14 750-square-kilometre area.

Water samples are analysed for uranium, fluorine, and pH. Stream sediments are analysed for zinc, copper, lead, nickel, cobalt, silver, manganese, iron, arsenic, molybdenum, tungsten, mercury, uranium, and antimony.

The survey encompasses diverse geologic terranes which include rocks of the Cache Creek, Takla, and Slide Mountain Groups. Exploration for gold and silver is presently concentrated in the Wells-Barkerville area, and adjacent to the trace of the Pinchi fault in the western survey area. Polymetallic vein deposits associated with the Cretaceous Naver intrusions are also being explored. It is anticipated that the geochemical survey results will enhance these efforts and broaden the scope for exploration in overburden covered areas.

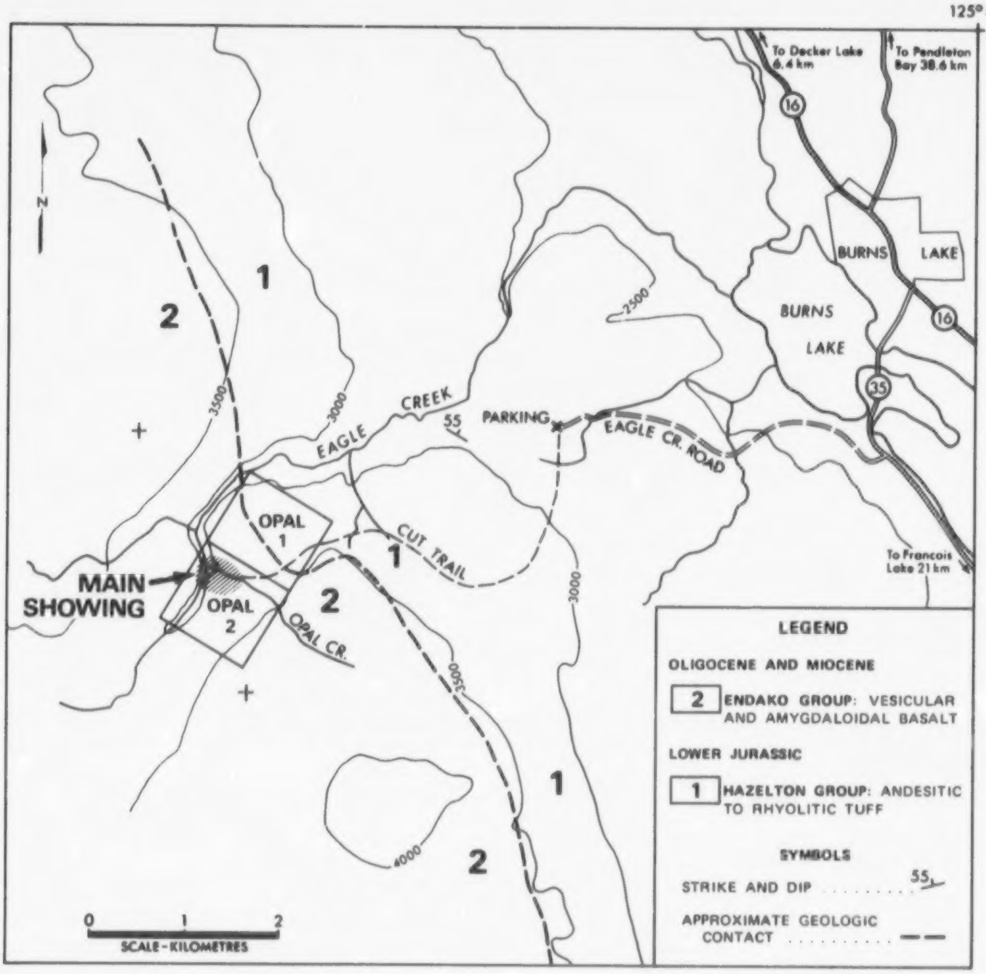

125° 45'
54° 15'
To Decker Lake 6.4 km
To Pendleton Bay 38.6 km
16
N
1
2
BURNS
LAKE
BURNS
LAKE
16
35
2500
3500
3000
EAGLE
CREEK
55
PARKING
EAGLE CR. ROAD
OPAL 1
CUT TRAIL
1
MAIN SHOWING
OPAL 2
2
OPAL CR.
3000
3500
To Francois Lake 21 km
1
4000
2
0
1
2
SCALE-KILOMETRES
LEGEND
OLIGOCENE AND MIOCENE
2 ENDAKO GROUP: VESICULAR AND AMYGDALOIDAL BASALT
LOWER JURASSIC
1 HAZELTON GROUP: ANDESITIC TO RHYOLITIC TUFF
SYMBOLS
STRIKE AND DIP
55
APPROXIMATE GEOLOGIC CONTACT

Figure 57. Location and access map of Eagle Creek Opal occurrence.

EAGLE CREEK OPAL OCCURRENCE
(93K/4W)

By T. G. Schroeter

INTRODUCTION

The Opal 1 and Opal 2 claims (which cover the Eagle Creek opal occurrence, Mineral Inventory 95), located approximately 6.5 kilometres west of Burns Lake, were examined on October 12, 1984. The assessment was at the request of the village of Burns Lake and District Chamber of Commerce to create a No Staking Reserve to protect an area with agate and opal occurrences from future staking of mineral claims so that the public can utilize it as a recreational area for the purpose of 'rock hounding.'

The area is accessed by a well-identified and well-kept walking trail, approximately 4.2 kilometres in length (*see* Fig. 57). Walking time to the collecting area is approximately 1 1/2 hours each way.

PROPERTY GEOLOGY

The property is underlain by flat-lying vesicular to amygdaloidal basalts of the Endako Group (Oligocene and Miocene age). Outcrops are restricted to creek valleys and locally include hoodoo structures. Elongated (up to 7.5 centimetre) and rounded leaf green agates occur in vesicles within the basalt. White and amber agates (up to 5 centimetres in diameter) and rare opals - including fire opals - have been reported.

RECOMMENDATIONS

It has been recommended that the principal areas of known agate and opal occurrences be protected by a *No Staking Reserve*.

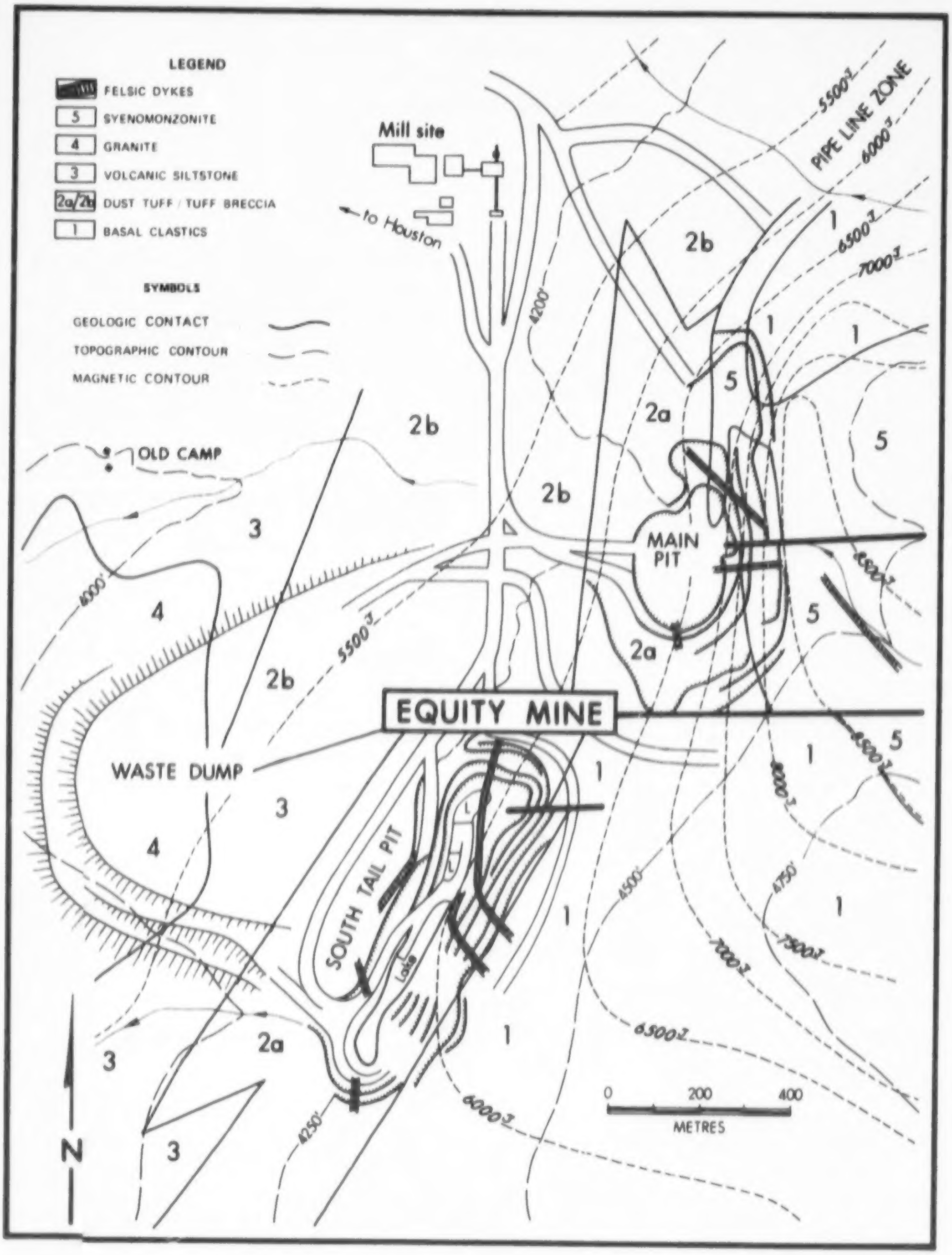

LEGEND
FELSIC DYKES
5 SYENOMONZONITE
4 GRANITE
3 VOLCANIC SILTSTONE
2a/2b DUST TUFF / TUFF BRECCIA
1 BASAL CLASTICS
SYMBOLS
GEOLOGIC CONTACT
TOPOGRAPHIC CONTOUR
MAGNETIC CONTOUR
Mill site
to Houston
PIPE LINE ZONE
5500γ
6000γ
6500γ
7000γ
1
2b
5
2a
OLD CAMP
3
4
4000'
4200'
MAIN PIT
8500γ
5500γ
EQUITY MINE
WASTE DUMP
SOUTH TAIL PIT
Lake
8000γ
4500'
4750'
7500γ
7000γ
6500γ
6000γ
4250'
N
0
200
400
METRES

Figure 58. Geology of the Equity minesite.

UPDATE ON THE GEOLOGY AND MINERALIZATION IN THE BUCK CREEK AREA
THE EQUITY SILVER MINE REVISITED
(93L/1W)

By B. N. Church

INTRODUCTION

This report includes the results of regional geological evaluations in the Houston area and examination of the open pit operation at the Equity Silver mine in July 1984. Current activity on the Equity property concerns mining the Main Zone ore and exploration drilling on the new Pipe Line Zone. The South Tail pit, which has supplied most of the ore to date is now abandoned (Fig. 58 and Plate IV).

Rock samples collected during regional mapping in the Buck Creek map sheet (Church, 1972) were analysed by J. Barakso of Min-En Laboratories for pathfinder and ore elements including Ag, As, Au, Cd, Co, Cu, Fe, Hg, Mo, Ni, Pb, and Zn. Contour maps prepared from these data showed 'bulls-eye' patterns around what is now the Equity Silver mine. Recently, Barakso extended his analyses to include Ba, F, Sn, and Sr plus the major elements Ca, K, Mg, and Na. Contour patterns for these support the earlier findings (Kowalchuk, *et al.*, 1984). It was concluded that the geochemical dispersion reflects a genetic relationship between the Goosly syenomonzonite body and the Equity ore deposit.

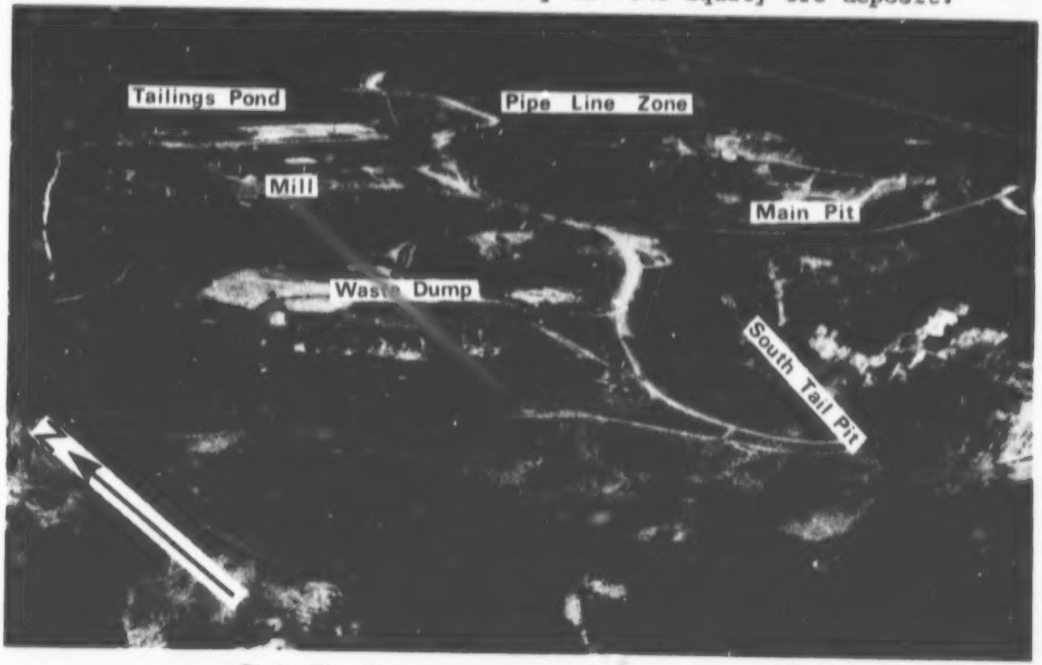


Plate IV. Panoramic view of Equity Silver mine.

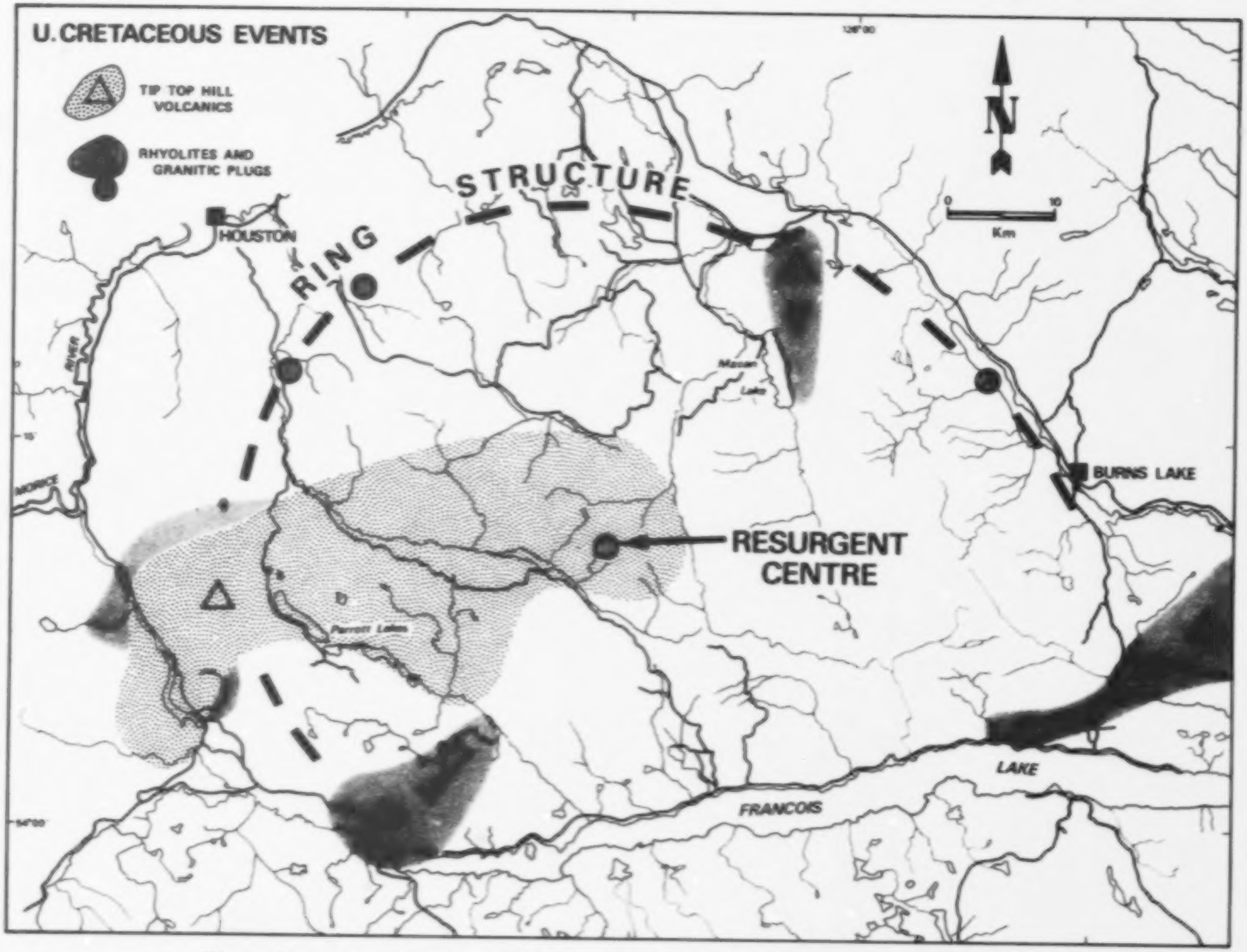
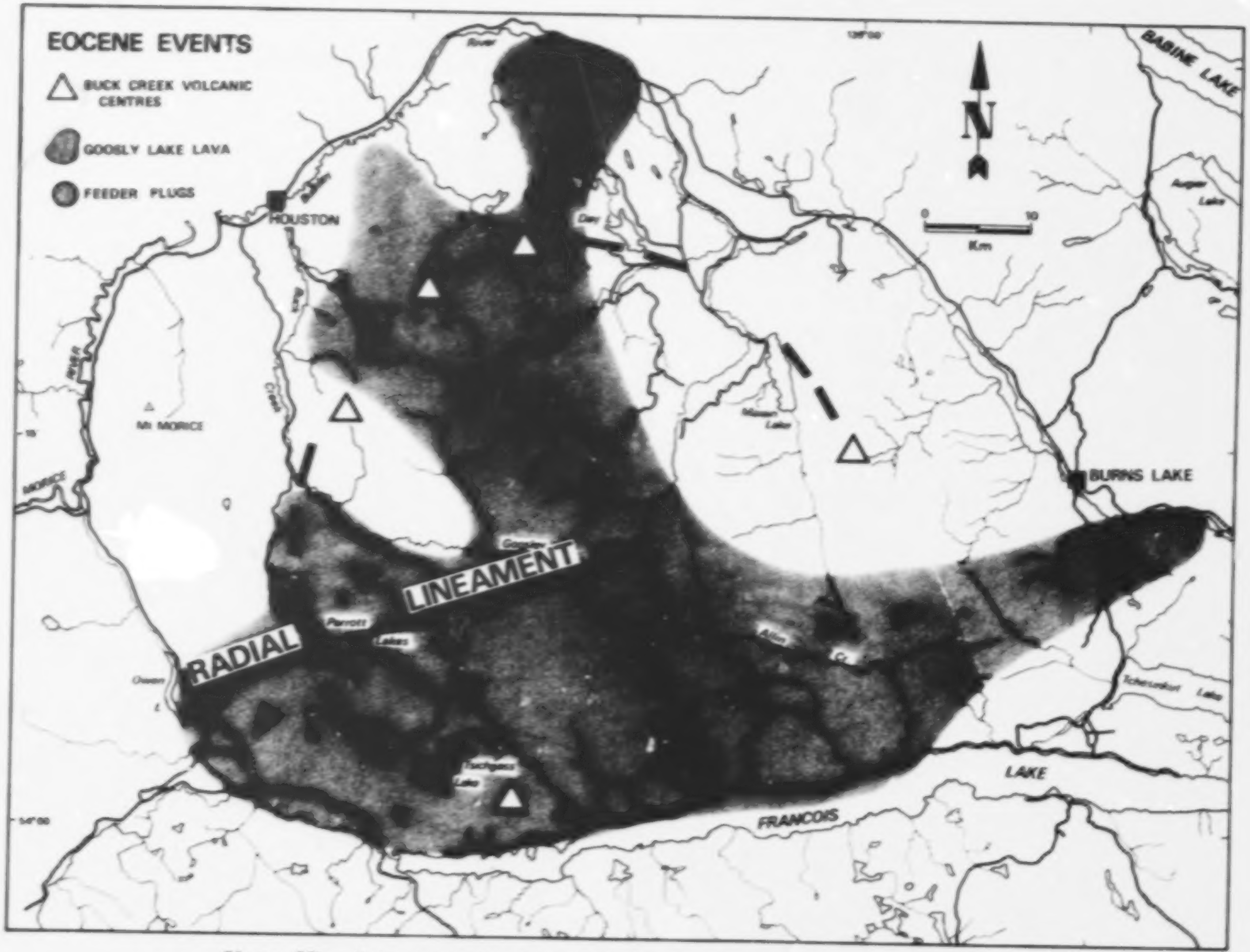
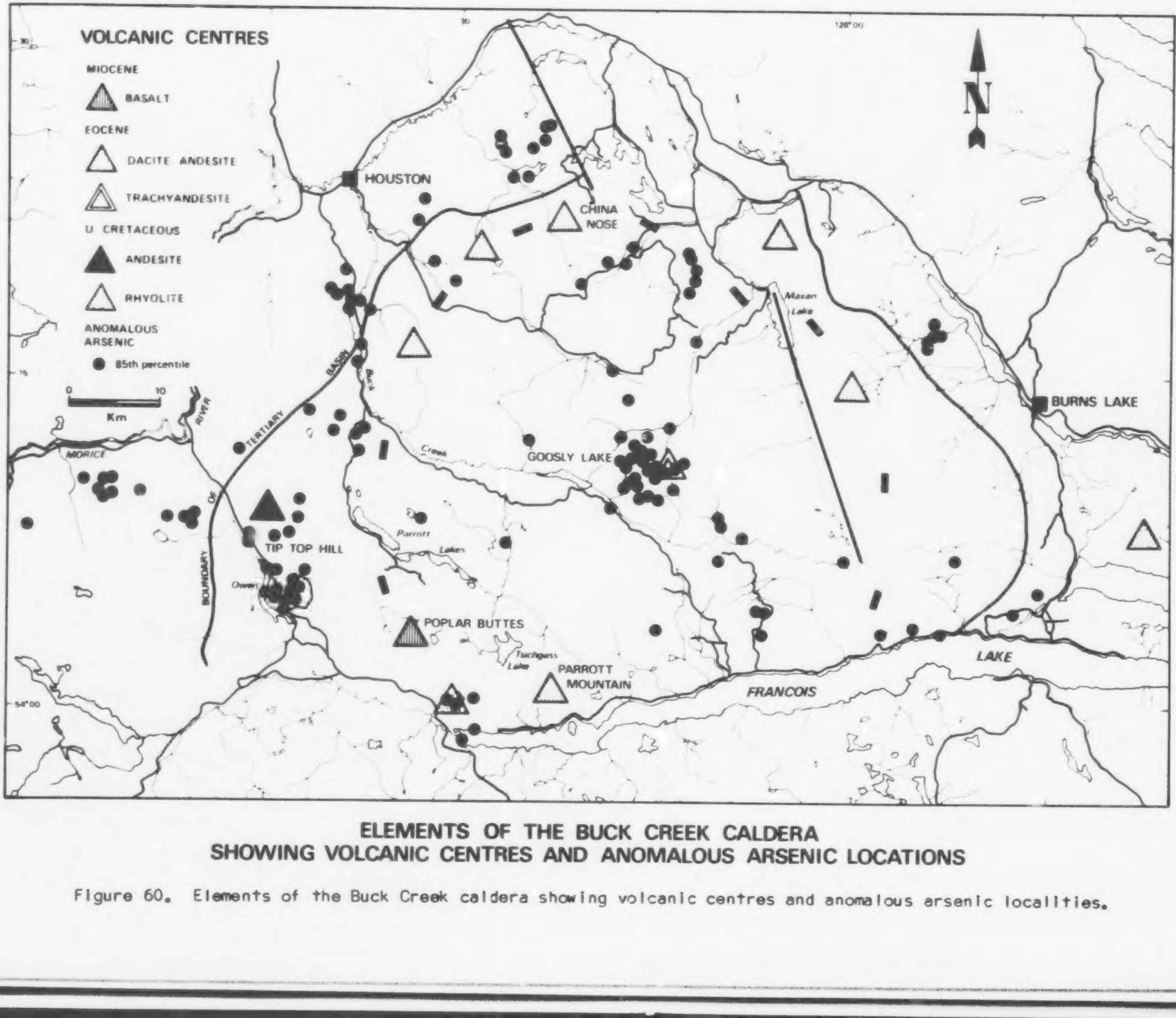

U. CRETACEOUS EVENTS
TIP TOP HILL VOLCANICS
RHYOLITES AND GRANITIC PLUGS
N
0
10
Km
HOUSTON
RING STRUCTURE
RIVER
MORICE
Maxan Lake
Parrott Lakes
BURNS LAKE
RESURGENT CENTRE
FRANCOIS
LAKE

Figure 59a. Volcanogenesis of the Buck Creek basin, Upper Cretaceous events.



EOCENE EVENTS
△ BUCK CREEK VOLCANIC CENTRES
GOOSLY LAKE LAVA
FEEDER PLUGS
N
0 10
Km
126°00
54°00
BABINE LAKE
Augier Lake
River
HOUSTON
Bulkley
Day
Buck Creek
Morice River
Mt MORICE
Maxan Lake
BURNS LAKE
Goosly
LINEAMENT
RADIAL
Parrott Lakes
Owen L
Allin Cr
Tchesinkut Lake
LAKE
FRANCOIS

Figure 59b. Volcanogenesis of the Buck Creek basin, Tertiary events.


VOLCANIC CENTRES
MIOCENE
BASALT
EOCENE
DACITE ANDESITE
TRACHYANDESITE
U CRETACEOUS
ANDESITE
RHYOLITE
ANOMALOUS ARSENIC
85th percentile
0
10
Km
N
30
120°00
15
54°00
HOUSTON
CHINA NOSE
BURNS LAKE
Maxan Lake
GOOSLY LAKE
TIP TOP HILL
Owen
POPLAR BUTTES
PARROTT MOUNTAIN
Tsichgass Lake
Parrott Lakes
Buck Creek
TERTIARY BASIN
BOUNDARY OF
MORICE RIVER
FRANCOIS LAKE

ELEMENTS OF THE BUCK CREEK CALDERA
SHOWING VOLCANIC CENTRES AND ANOMALOUS ARSENIC LOCATIONS

Figure 60. Elements of the Buck Creek caldera showing volcanic centres and anomalous arsenic localities.

According to this model, the Goosly stock and accompanying dykes intruded Mesozoic host rocks mobilizing juvenile and connate solutions. This produced a broad alteration halo containing sulphide disseminations, replacement lenses, and vein fillings. It is possible that the Goosly stock was only a source of heat and solutions which redistributed and concentrated ore metals; however, there is evidence that some elements moved directly from the intrusion.

This mineralization resulted in the Equity deposit with a total estimated reserve of 27.4 million tonnes averaging 105.6 grams per tonne silver, 0.95 gram per tonne gold, 0.38 per cent copper, and 0.08 per cent antimony.

GEOLOGICAL SETTING

The geology of the Buck Creek area and Equity mine was discussed in detail previously in several Ministry publications by Church (1969 to 1973 and 1981) and Schroeter (1974, 1979).

The Equity mine is located within an erosional window of uplifted Eocene and Lower Cretaceous beds near the mid-point of the Buck Creek basin. This central uplift appears to be the result of a resurgency in a large caldera. The perimeter of the 'Buck Creek caldera' is delineated roughly by a series of rhyolite outliers and the semi-circular alignment of Eocene volcanic centres scattered between Francois Lake, Houston, and Burns Lake. A prominent 30-kilometre-long lineament, trending west-southwest from the mine and central uplift, appears to be a radial fracture coinciding with the eruptive axis of the Tip Top Hill volcanics (77.1±2.7 Ma) and a line of syenomonzonite stocks and feeder dykes to an assemblage of 'moat volcanics', which include the Goosly Lake lavas and breccias (49.7±1.8 Ma) (Figs. 59 and 60).

The principal host rocks at the Equity mine are Mesozoic volcanic and sedimentary beds correlative in part with fossiliferous* Skeena Group units exposed on the north shore of Francois Lake. The chief sulphides are pyrite, chalcopyrite, pyrrhotite, and tetrahedrite, with minor amounts of galena, sphalerite, and some sulphosalts. These are accompanied by clay minerals, chlorite, specularite, and locally sericite, pyrophyllite, andalusite, tourmaline, and minor amounts of scorzalite and corundum.

LITHOGEOCHEMISTRY

A primary lithogeochemical study was completed on 2 119 rock samples from the Buck Creek map-area, including the Equity mine site. The results for precious and base metals highlight the known ore deposits, many mineral showings, and some previously unrecorded mineral occurrences.

---

*Conglomerates containing pelecypods and gastropods including *Trigonia emoryi*, Lower Cretaceous.

Arsenic proved to be an excellent pathfinder for the ore minerals and confirmed caldera structures. The regional pattern for anomalous arsenic is annular in general form with a centrally located concentration over the resurgent area of the caldera (Fig. 60).

Dispersion of elements in vicinity of the Equity mine was described by Church, *et al.*, (1981) and Kowalchuck, *et al.*, (1984). Figure 61 is a reproduction from Kowalchuck with K added to the Ag, As, Cu composite pattern. To ensure a realistic representation of results contours for these elements were constructed using a $1/r^2$ radial weighting factor applied to a grid of moving average values.

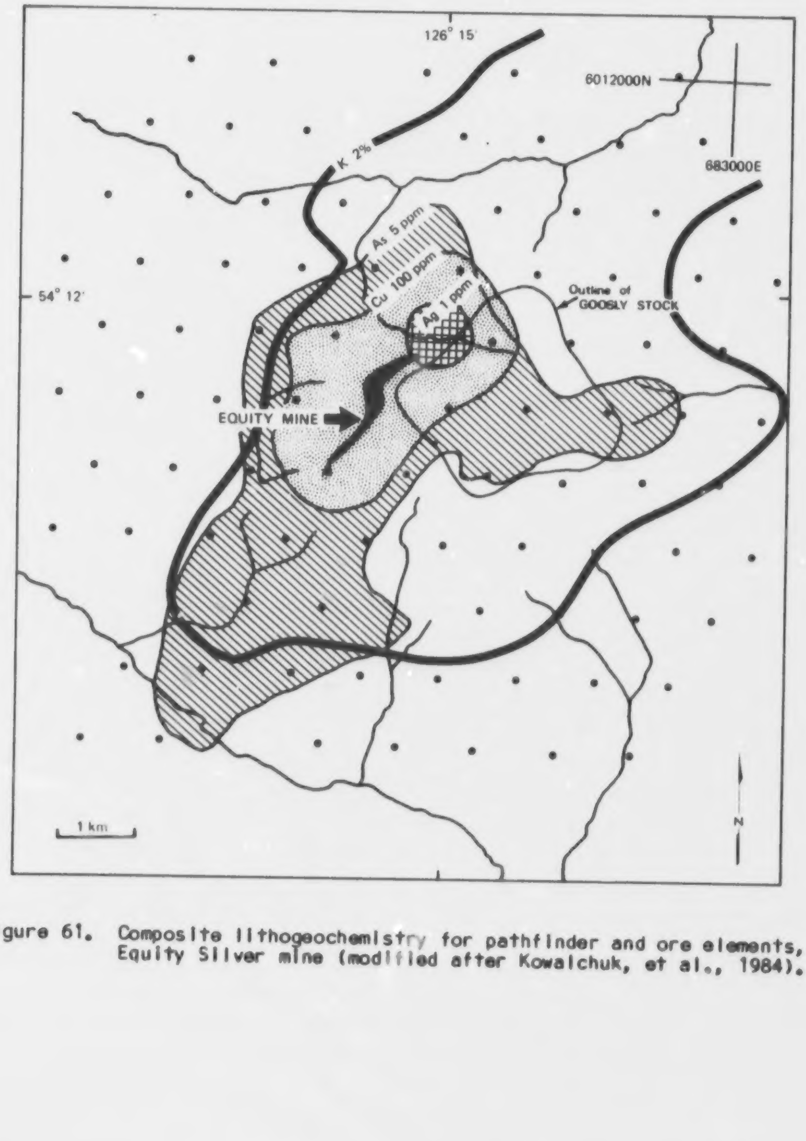

126° 15'
6012000N
683000E
K 2%
As 5 ppm
Cu 100 ppm
Ag 1 ppm
Outline of GOOSLY STOCK
54° 12'
EQUITY MINE
1 km
N

Figure 61. Composite lithogeochemistry for pathfinder and ore elements, Equity Silver mine (modified after Kowalchuk, et al., 1984).

The element contours are mostly closed about the Equity orebody. Silver exceeds 1 ppm within a 1-square-kilometre area covering part of the Main Zone and the undeveloped Pipe Line Zone to the northeast. Copper is above 100 ppm over the entire orebody and distal terrain radially for about 1 kilometre. Arsenic greater than 5 ppm includes much of the pre-Tertiary window containing the ore zone, the Goosly stock, and a gossan zone at the east contact of the stock. Potassium shows the greatest dispersion forming a broad northeast-elongated aureole extending well beyond the Goosly stock and metal anomalies.

The transgression of element contours across geological boundaries is a conspicuous feature of the Equity deposit. Sulphides are found throughout the Skeena stratigraphy including sulphide stringers in the basal clastics, ore mineralization of the dust tuff, and disseminations in the overlying volcanic pile and subjacent Tertiary rocks. This evidence points to the Goosly stock as the main source of mineralizing solutions.

DISCUSSION

Mining on the Equity property since April 1980 has afforded an excellent opportunity to study this deposit (Fig. 58). With recent delineation of the Pipe Line Zone, north of the main pit, the full length of the orebody is now known to exceed 1 500 metres. Open pit excavation began on the South Tail Zone, situated midway between the Waste Dump granite and the Goosly syenomonzonite stock and is now underway on the Main Ore Zone to the northeast at the contact of the syenomonzonite. The Pipe Line Zone, centred about 1.5 kilometres northeast of the Waste Dump granite, appears to be an extension of the Main Zone wrapping around the northwest flank of the syenomonzonite. A peculiar ring dyke-like appendage of the syenomonzonite is exposed in the main pit where it divides part of the ore and strikes toward the Pipe Line Zone.

A number of conspicuous felsic dykes are exposed in the pits. These consist of bladed feldspar porphyry offshoots of the syenomonzonite stock, pulaskite feeder dykes related to the Goosly Lake lavas, and young quartz-feldspar porphyry dykes that cut the syenomonzonite body and adjacent ore zone. Emplacement of some of these dykes during the mineralizing episode is indicated by local hydrothermal alteration of the dykes to clay minerals, the apparent damming and concentration of sulphides along some intrusive contacts, and the occurrence of disseminations and veinlets of ore minerals within some dykes (Plates V and VI).

Crystal fractionation of the Goosly intrusions is apparently responsible for the wide range of magmas in the line of gabbro-syenomonzonite stocks, related dykes, and Goosly Lake volcanic rocks. This evolution results in a regular progression in chemistry and mineralogy from basic to felsic rock types (Fig. 62 and Table 1). The natural products of this process

TABLE 1
CHEMICAL ANALYSES OF GOOSLY INTRUSIVE ROCKS

	1	2	3	4	5	6	7	8	9
Oxide recalculated to 100:									
SiO_2	49.12	49.35	51.77	51.64	51.84	53.90	54.65	54.79	56.11
TiO_2	1.51	1.31	1.42	2.89	1.46	1.51	1.88	1.35	1.35
Al_2O	16.66	16.34	16.68	16.00	17.56	17.25	17.57	17.60	17.63
Fe_2O_3	2.49	2.35	1.54	6.28	2.81	5.31	4.11	3.48	2.94
FeO	6.12	7.42	7.60	4.63	4.79	2.42	3.75	4.29	3.46
MnO	0.20	0.17	0.19	0.15	0.14	0.11	0.14	0.14	0.06
MgO	6.85	11.93	7.89	4.42	5.78	3.85	3.98	4.64	2.73
CaO	13.55	6.83	8.11	6.55	9.88	7.77	6.25	6.35	6.51
Na_2O	3.00	3.62	4.41	5.42	4.82	5.08	4.25	3.86	5.60
K_2O	0.50	0.68	0.39	2.02	0.92	2.80	3.42	3.50	3.61
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Oxides as determined:									
H_2O-	2.65	4.27	3.02	2.80	4.84	1.10	1.90	1.31	2.51
H_2O+	0.90	2.02	0.72	0.58	0.51	0.89	0.18	0.37	0.50
CO_2	0.69	0.41	5.50	0.10	0.60	1.15	0.07	40.01	0.82
S	0.04	0.05	0.24	0.06	0.01	0.62	0.40	0.02	0.09
P_2O_5	0.28	0.09	0.15	0.27	0.18	0.59	0.91	0.71	2.64
BaO	0.07	0.02	0.07	0.04	0.02	0.28	0.27	0.29	0.27
SrO	0.05	0.05	0.07	0.04	0.05	0.12	-	0.14	0.08
Molecular Norm:									
Q_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Or	2.95	3.82	2.27	11.93	5.36	16.40	20.15	20.58	21.02
Ab	26.88	31.71	39.00	46.93	39.40	43.06	38.02	34.47	43.74
Ne	0.00	0.00	0.00	1.01	1.94	1.27	0.00	0.00	3.47
An	30.48	25.71	24.22	13.37	23.24	15.87	18.72	20.27	12.14
Wo	14.65	2.94	6.17	7.64	10.03	8.93	4.88	4.43	7.87
En	2.93	2.49	4.17	0.00	0.00	0.00	6.83	9.39	0.00
Fs	1.41	0.83	2.19	0.00	0.00	0.00	1.93	2.85	0.00
Fo	11.97	22.24	12.97	9.15	11.80	7.90	3.10	2.52	5.57
Fa	5.75	7.40	6.83	0.00	4.95	0.00	0.88	0.76	1.86
Il	0.38	0.46	0.59	3.92	0.29	2.08	1.21	1.11	1.30
Mt	2.60	2.40	1.59	4.72	2.89	2.45	4.28	3.62	3.03
Hm	0.00	0.00	0.00	1.23	0.00	2.03	0.00	0.00	0.00
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Key to Analyses

Geology, Exploration and Mining in British Columbia, 1969, p. 148 (No. 7); 1970, p. 124, (Nos. 1, 4, and 6); and 1970, p. 138 (No. 9).

New analyses Nos. 2, 3, and 5 from Gillian sill and No. 8 from the Goosly stock.

were heat, water, and fugitives such as potassium, boron, and phosphorus (significant components in the altered rocks of the Equity mine) and other ore constituents.

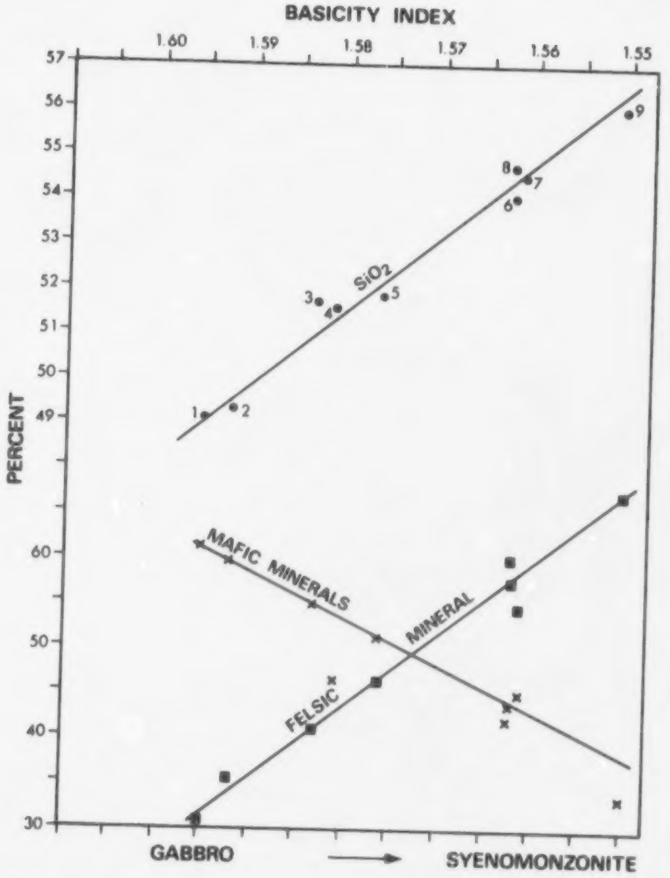


Figure 62. Mixing diagram showing chemical and mineralogical consanguinity of Goosly intrusions in the Buck Creek area (analyses numbers are keyed to data in Table 1).

METALLOGENIC MODEL

A model suggesting the sequence of events leading to mineralization at the Equity silver mine is illustrated on Figure 63. Initially, a small granitic stock intruded Skeena Group (Lower Cretaceous) volcanics and metasediments resulting in weak porphyry copper-molybdenum mineralization. Several million years later a larger gabbro-syenomonzonite body, with many offshoot dykes, was emplaced several hundred metres to the east, brecciating the adjacent dacite dust tuff unit of the Skeena Group (stage 2). Outward movement of hydrothermal solutions from the

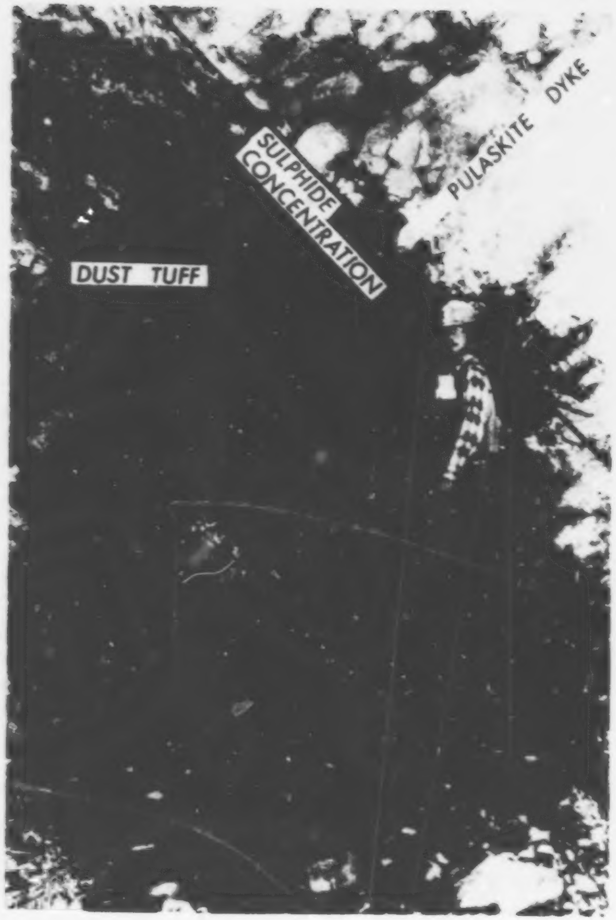

SULPHIDE CONCENTRATION
PULASKITE DYKE
DUST TUFF

Plate V. Pulaskite dyke with sulphide ponded (?) at the footwall contact, veinlets of ore sulphides occur within the dyke.

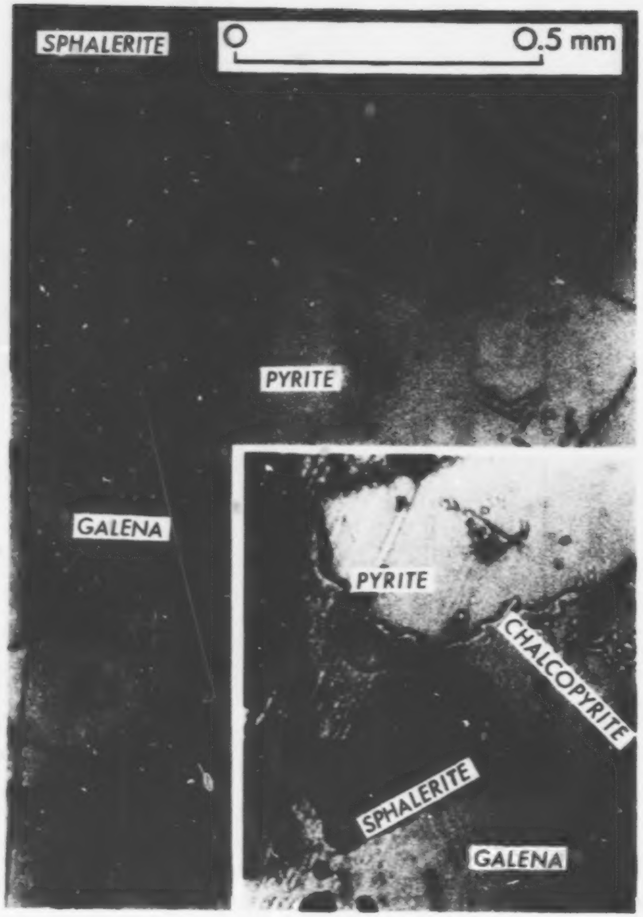

SPHALERITE
0
0.5 mm
PYRITE
GALENA
PYRITE
CHALCOPYRITE
SPHALERITE
GALENA

Plate VI. Photomicrograph of a sulphide veinlet within the Tertiary pulaskite dyke.

syenomonzonite produced a broad aureole of alteration and sulphide dissemination, replacement, and filling (stages 3 and 4). A late stage hydrothermal event followed, accompanying resurgence of igneous activity. These events produced silver, copper, arsenic, and potassium lithogeochemical haloes about the Equity ore zone and to some extent around the syenomonzonite intrusion.

These evaluations are intended to shed more light on the Equity deposit with the view to assisting further exploration in the Buck Creek area.

REFERENCES

Barasko, J. J. and Church, B. N. (1973): Rock Geochemistry in the Owen Lake-Goosly Lake Area, *B.C. Ministry of Energy, Mines & Pet. Res.*, Prelim. Map Nos. 13a to i.

Church, B. N. (1969): SG (Sam Goosly), *B.C. Ministry of Energy, Mines & Pet. Res.*, GEM, 1969, pp. 142-148.

..... (1970): Geology of the Owen Lake, Parrott Lakes, and Goosly Lake Areas, *B.C. Ministry of Energy, Mines & Pet. Res.*, GEM, 1970, pp. 119-128.

..... (1972): Geology of the Buck Creek Area, *B.C. Ministry of Energy, Mines & Pet. Res.*, GEM, 1972, pp. 353-363.

Church, B. N. and Hutter, J. F. (1973): Sam Goosly, *B.C. Ministry of Energy, Mines & Pet. Res.*, GEM, 1973, pp. 334-338.

Church, B. N., Barasko, J. J., and Bowman, A. F. (1976): The Endogenous Distribution of Minor Elements in the Goosly-Owen Lake Area of Central British Columbia, *C.I.M.*, 1979, Bull. 69, pp. 88-95.

Church, B. N., Barakso, J. J., and Ball, D. (1980): Computer Processing of Geochemical Data Showing the Primary Dispersion of Elements near Equity Mine, Central British Columbia, *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1979, Paper 1980-1, pp. 25-31.

Kowalchuk, J. M., Church, B. N., Bradshaw, P.M.D., and Barakso, J. J. (1984): Lithogeochemistry at the Equity Silver Mine, *Western Miner*, 1984, Vol. 57, No. 4, pp. 50-54.

Ney, C., Anderson, J. M., and Panteleyev, A. (1972): Discovery, Geolologic Setting and Style of Mineralization, Sam Goosly Deposit, British Columbia, *C.I.M.*, 1972, Bull. 65, pp. 53-64.

Schroeter, T. G. (1974): Northwestern British Columbia, Sam Goosly, *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1974, Paper 1975-1, p. 79.

..... (1979): Mineral Property Examinations, Sam Goosly, *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1979, Paper 1980-1, pp. 122-125.

Wetherell, D. G. (1979): Geology and Ore Genesis of the Sam Goosly Copper-Silver-Antimony Deposit, British Columbia, *Univ. of B.C.*, 1979, M.Sc. Thesis, 208 pp.

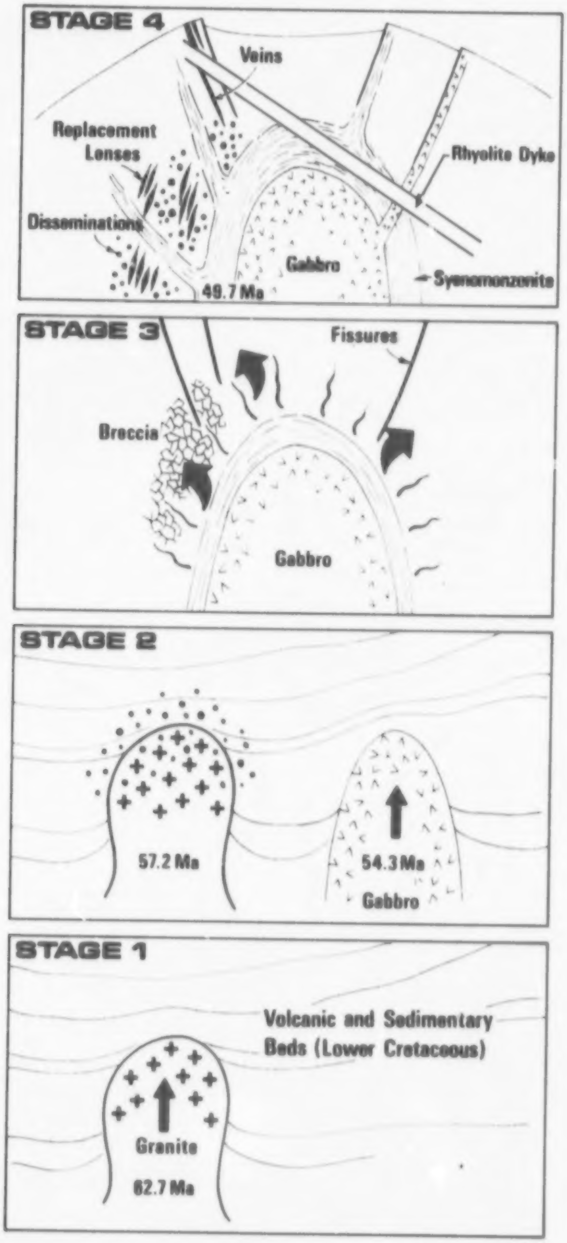

STAGE 4
Veins
Replacement Lenses
Rhyolite Dyke
Disseminations
Gabbro
49.7 Ma
Syenomonzonite
STAGE 3
Fissures
Breccia
Gabbro
STAGE 2
57.2 Ma
54.3 Ma
Gabbro
STAGE 1
Volcanic and Sedimentary Beds (Lower Cretaceous)
Granite
62.7 Ma

Figure 63. Metallogenic model showing the stages of igneous intrusion leading to mineralization at the Equity Silver mine.

Wetherell, D. G., Sinclair, A. J., and Schroeter, T. G. (1978): Preliminary Report on the Sam Goosly Copper-Silver Deposit, British Columbia, *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1978, Paper 1979-1, pp. 133-137.

Wojdak, P. J. (1974): Alteration of the Sam Goosly Copper-Silver Deposit, British Columbia, *Univ. of B.C.*, 1974, M.Sc. Thesis, 116 pp.

TABLE 2

SILICATE ANALYSES CALCULATED FROM MODAL DATA COMPARED WITH CHEMICAL RESULTS

	WASTE DUMP GRANITE		GOOSLY SYENOMONZONITE	
Oxides Recast to 100%	1 Calculated	2 Chemical	3 Calculated	4 Chemical
SiO_2	66.8	66.2	54.3	54.6
Al_2O_3	17.2	16.0	19.9	17.6
Fe_2O_3	2.6	2.1	6.6	4.1
FeO	1.3	1.6	3.4	3.8
MgO	1.1	1.3	1.6	4.0
CaO	4.0	3.2	6.2	6.3
Na_2O	3.5	4.3	3.9	4.3
K_2O	3.4	3.6	4.1	3.4
H_2O	0.1	1.7	Tr	1.9
	100.00	100.00	100.00	100.00
Modal %				
Quartz	25		2	
Orthoclase	19		25	
Plagioclase (An_{45})	50		58	
Biotite	4		2	
Augite	-		8	
Magnetite	2		5	
	100		100	

Key to Analyses:

1 - Silicate composition calculated from modal results on granite (GEM, 1969, p. 146)

2 - Silicate composition from chemical analysis of granite No. 1 (GEM, 1969, p. 148, No. 1 in Table)

3 - Silicate composition calculated from modal results on syenomonzonite (GEM, 1969, p. 147)

4 - Silicate composition from chemical analysis of syenomonzonite (GEM, 1969, p. 148, No. 2 in Table)

A COMPUTER PROGRAM FOR THE ESTIMATION OF OXIDE COMPOSITION FROM MODAL ANALYSES OF PLUTONIC ROCKS FROM THE BUCK CREEK AREA

(93L/1W)

By B. N. Church

The calculation of oxide composition of plutonic rocks from modal mineralogy affords an inexpensive method of utilizing the many petrological plots and variation diagrams designed only for silicate analyses. To this end Wahlstrom (1955, pp. 88, 89) outlined a simple method to compute weight percentage oxides from constituent minerals.

In Table 1 (pages 190 and 191) a computerized method for the same purpose has been devised to facilitate study of the crystalline plutonic rocks of the Buck Creek area. This procedure allows comparisons with the fine-grained volcanic suite for which only chemical data are available. Although the computer program has been written specifically for the TI 99-4/A computer, this is a sufficiently simple form of the Basic language to be applicable using most desk-top computers.

Percentage estimates from a choice of 11 of the most common minerals in plutonic rocks are input to the program. Output is given as weight percentage of nine of the main oxides including FeO, Fe_2O_3, and H_2O.

The method is tested using available mineral and chemical data for the Goosly syenomonzonite stock and Waste Dump granite on the Equity mine property (Table 2, page 188). Comparison of calculated and chemical results for these rocks yields generally favourable comparisons, especially for total silica, alkalies, and lime values. Some discrepancies in ferromagnesian values might be expected owing to FeO-MgO diadochy in silicate minerals and inherent analytical difficulties in determining FeO/Fe_2O_3 ratios and H_2O content. Identifications of mineral specimens using X-ray methods could improve the estimates of oxide composition.

REFERENCE

Wahlstrom, E. E. (1955): Petrographic Mineralogy, *John Wiley & Sons Inc.*, New York, 408 pp.

TABLE 1
COMPUTER PROGRAM IN T1 BASIC TO DETERMINE SILICATE COMPOSITIONS FROM MODAL MINERALOGY

```
10 REM  "xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx"
20 REM  "x                                                   x"
40 REM  "x CALCULATE SILICATE COMPOSITIONS FROM MODAL DATA   "
60 REM  "x                                                   x"
80 REM  "xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx"
100 REM
120 REM
140 INPUT "SAMPLE NO.";Z(0)
160 INPUT "QUARTZ    ";Z(1)
180 INPUT "ORTHOCLASE";Z(2)
200 INPUT "ALBITE    ";Z(3)
220 INPUT "OLIGOCLASE";Z(4)
240 INPUT "ANDESINE  ";Z(5)
260 INPUT "LABRADORIT";Z(6)
280 INPUT "MUSCOVITE ";Z(7)
300 INPUT "BIOTITE   ";Z(8)
320 INPUT "HORNBLENDE";Z(9)
340 INPUT "AUGITE    ";X(1)
360 INPUT "MAGNETITE ";X(2)
365 REM
366 REM  S.G. FACTORS
380 Q(0)=2.65*Z(1)
400 K(0)=2.57*Z(2)
420 A(0)=2.62*Z(3)
440 O(0)=2.65*Z(4)
460 P(0)=2.68*Z(5)
480 L(0)=2.70*Z(6)
500 W(0)=2.84*Z(7)
520 B(0)=3.00*Z(8)
540 H(0)=3.30*Z(9)
560 E(0)=3.00*X(1)
580 M(0)=4.96*X(2)
590 REM
600 Y=Z(1)+Z(2)+Z(3)+Z(4)+Z(5)+Z(6)+Z(7)+Z(8)+Z(9)+X(1)+X(2)
610 REM
620 REM  CALCULATE WEIGHT %
640 Q(9)=100*Q(0)/Y
660 K(9)=100*K(0)/Y
680 A(9)=100*A(0)/Y
700 O(9)=100*O(0)/Y
720 P(9)=100*P(0)/Y
740 L(9)=100*L(0)/Y
760 W(9)=100*W(0)/Y
780 B(9)=100*B(0)/Y
800 H(9)=100*H(0)/Y
820 E(9)=100*E(0)/Y
840 M(9)=100*M(0)/Y
842 REM
850 REM
860 Q(1)=1.00*Q(9)
880 K(1)=.647*K(9)
900 K(2)=.184*K(9)
920 K(8)=.169*K(9)
940 A(1)=.687*A(9)
960 A(2)=.195*A(9)
980 A(7)=.118*A(9)
1000 O(1)=.636*O(9)
1020 O(2)=.230*O(9)
1040 O(6)=.040*O(9)
1060 O(7)=.094*O(9)
1080 P(1)=.587*P(9)
1100 P(2)=.264*P(9)
1120 P(6)=.080*P(9)
1140 P(7)=.070*P(9)
1160 L(1)=.534*L(9)
1180 L(2)=.298*L(9)
```

```
1200 L(6)=.120*L(9)
1220 L(7)=.047*L(9)
1240 W(1)=.452*W(6)
1260 W(2)=.385*W(6)
1280 W(8)=.110*W(6)
1300 W(9)=.045*W(6)
1320 B(1)=.425*B(6)
1340 B(2)=.172*B(6)
1360 B(3)=.022*B(6)
1380 B(4)=.027*B(6)
1400 B(5)=.250*B(6)
1420 B(8)=.090*B(6)
1440 B(9)=.014*B(6)
1460 H(1)=.480*H(9)
1480 H(2)=.080*H(9)
1500 H(3)=.050*H(9)
1520 H(4)=.110*H(9)
1540 H(5)=.140*H(9)
1560 H(6)=.120*H(9)
1580 H(7)=.015*H(9)
1600 H(8)=.005*H(9)
1620 C(1)=.472*C(9)
1640 C(2)=.074*C(9)
1660 C(3)=.046*C(9)
1680 C(4)=.069*C(9)
1700 C(5)=.126*C(9)
1720 C(6)=.209*C(9)
1740 M(3)=.690*M(9)
1760 M(4)=.310*M(9)
1765 REM
1780 REM  CALCULATE OXIDE %
1800 S(0)=D(1)+[illegible]
1820 D(0)=[illegible]
1840 U(0)=B(3)+[illegible]
1860 V(0)=B(4)+H(4)+C(4)+M(4)
1880 E(0)=B(5)+H(5)+[illegible]
1900 [illegible]
1920 [illegible]
1940 [illegible]
1950 J(0)=[illegible]
1961 REM
1962 [illegible]
1963 REM
1964 S(1)=100*S(0)/T
1966 D(1)=100*D(0)/T
1968 U(1)=100*U(0)/T
1970 V(1)=100*V(0)/T
1972 E(1)=100*E(0)/T
1974 G(1)=100*G(0)/T
1976 H(1)=100*H(0)/T
1978 K(1)=100*K(0)/T
1979 J(1)=100*J(0)/T
1980 PRINT "SAMPLE NO. ",[illegible]
1981 REM
2000 PRINT "SIO2   ",S(1)
2020 PRINT "AL2O3  ",D(1)
2040 PRINT "FE2O3  ",U(1)
2060 PRINT "FEO    ",V(1)
2080 PRINT "MGO    ",E(1)
2100 PRINT "CAO    ",G(1)
2120 PRINT "NA2O   ",H(1)
2140 PRINT "K2O    ",K(1)
2160 PRINT "H2O    ",J(1)
```

Note: Coefficients for the conversion of mineral species to constituent oxides have been adapted from Wahlstrom (1955, pp. 88, 89).

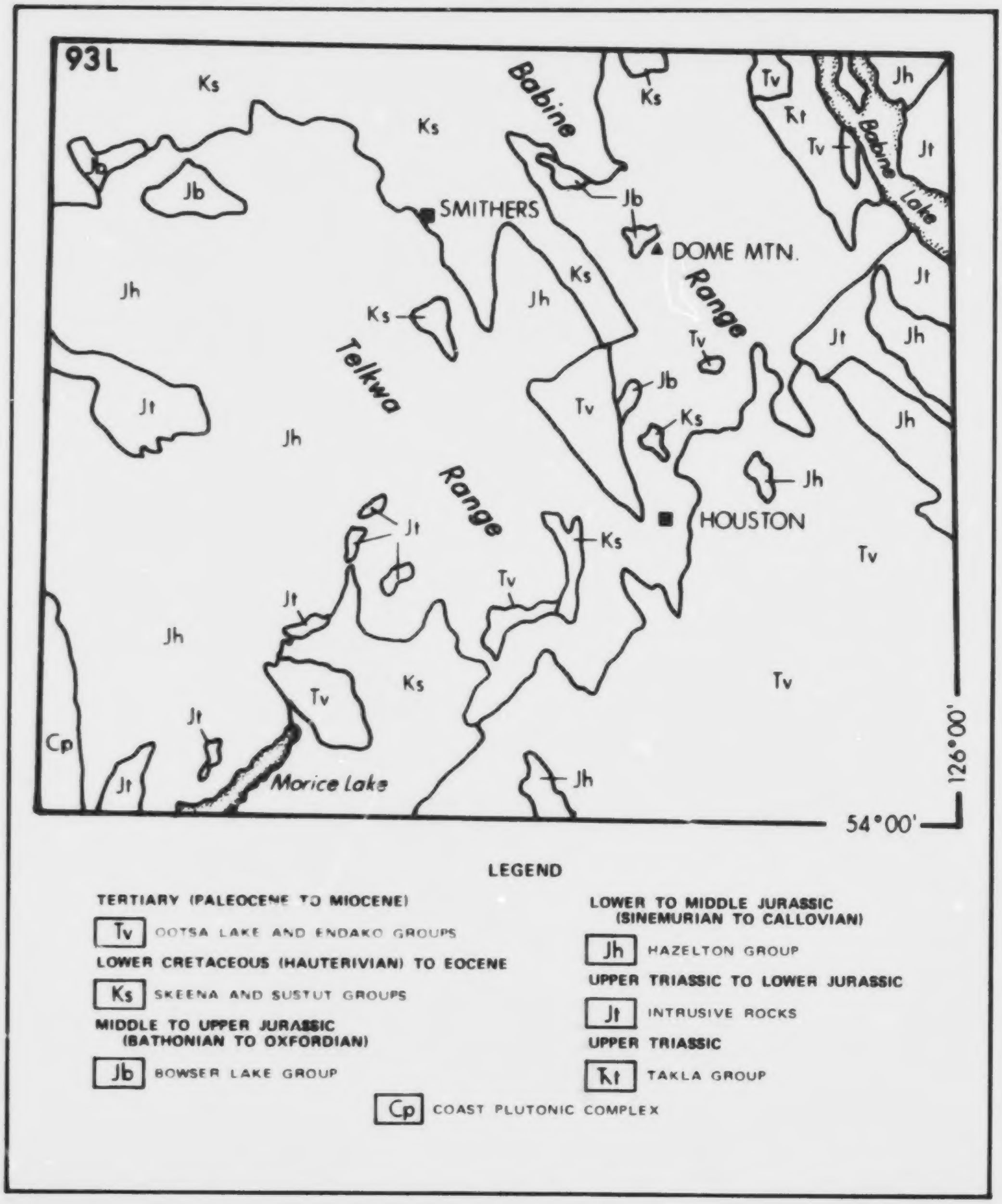

93L
Ks
Babine
Ks
Ks
Tv
Jh
Ŧt
Tv
Babine Lake
Jt
Jb
Jb
Jb
SMITHERS
DOME MTN.
Range
Ks
Jh
Jh
Jt
Jt
Jh
Ks
Telkwa
Tv
Jb
Tv
Jt
Jh
Ks
Jh
Jh
Range
HOUSTON
Jt
Range
Ks
Tv
Tv
Jt
Jh
Ks
Tv
Tv
Jt
Cp
Jt
Morice Lake
Jh
126°00'
54°00'
LEGEND
TERTIARY (PALEOCENE TO MIOCENE)
Tv OOTSA LAKE AND ENDAKO GROUPS
LOWER CRETACEOUS (HAUTERIVIAN) TO EOCENE
Ks SKEENA AND SUSTUT GROUPS
MIDDLE TO UPPER JURASSIC (BATHONIAN TO OXFORDIAN)
Jb BOWSER LAKE GROUP
LOWER TO MIDDLE JURASSIC (SINEMURIAN TO CALLOVIAN)
Jh HAZELTON GROUP
UPPER TRIASSIC TO LOWER JURASSIC
Jt INTRUSIVE ROCKS
UPPER TRIASSIC
Ŧt TAKLA GROUP
Cp COAST PLUTONIC COMPLEX

Figure 64. Location of Dome Mountain gold camp and general geology of the Smithers map-area.

GEOLOGY OF THE DOME MOUNTAIN GOLD CAMP
(93L/10, 15)

By D. G. MacIntyre

INTRODUCTION

This report summarizes preliminary results of a mapping project initiated in the Dome Mountain gold camp during the 1984 field season. A two person crew spent 20 field days on this project. This work was the first stage of a multi-year mapping project which ultimately will include all of the Babine Range. The objective of this project is to develop a metallogenic model for the wide variety of mineral deposit types present in the Babine Range. The initial phase of this project is concerned with gold-bearing quartz veins like those of the Dome Mountain gold camp.

LOCATION AND TOPOGRAPHY

Dome Mountain, which rises to 1 753 metres elevation, is 38 kilometres east of Smithers within the northwest-trending Babine Range. There is abundant vegetation and a general lack of outcrop on the lower slopes of Dome Mountain. The best outcrop occurs in creek beds and on the rounded crest of the mountain. The area is accessible either via the rough Deception Lake forest road from Telkwa or the Chapman Lake logging road, which is located east of the Babine Range. Although both routes ultimately lead to the top of Dome Mountain, neither route is passable during periods of wet weather.

EXPLORATION HISTORY

Prospectors first staked claims on Dome Mountain in about 1914 and these claims were actively explored until 1924. In 1923 and 1924, the Dome Mountain Mining Company, a newly formed subsidiary of the New York based Federal Mining and Smelting Company started underground workings on the Forks, Cabin, Jane and Ptarmigan veins. Of these, the Forks was considered the most favourable and a wagon road was constructed, a permanent camp established, and a steam-boiler plant for pumping and hoisting moved onto the property to aid in the underground development. However, in 1924, apparently discouraged by the lenticular nature of the ore veins and excessive water in the underground workings, all work was halted and the boiler-plant dismantled and removed from the property.

In 1932, Babine Gold Mines Limited optioned the Free Gold property, which is located 2 kilometres northeast of the Forks, and started underground workings to cross cut several small gold-bearing quartz veins. Bulk shipments were made in 1938 and 1940; in 1949 title was transferred to

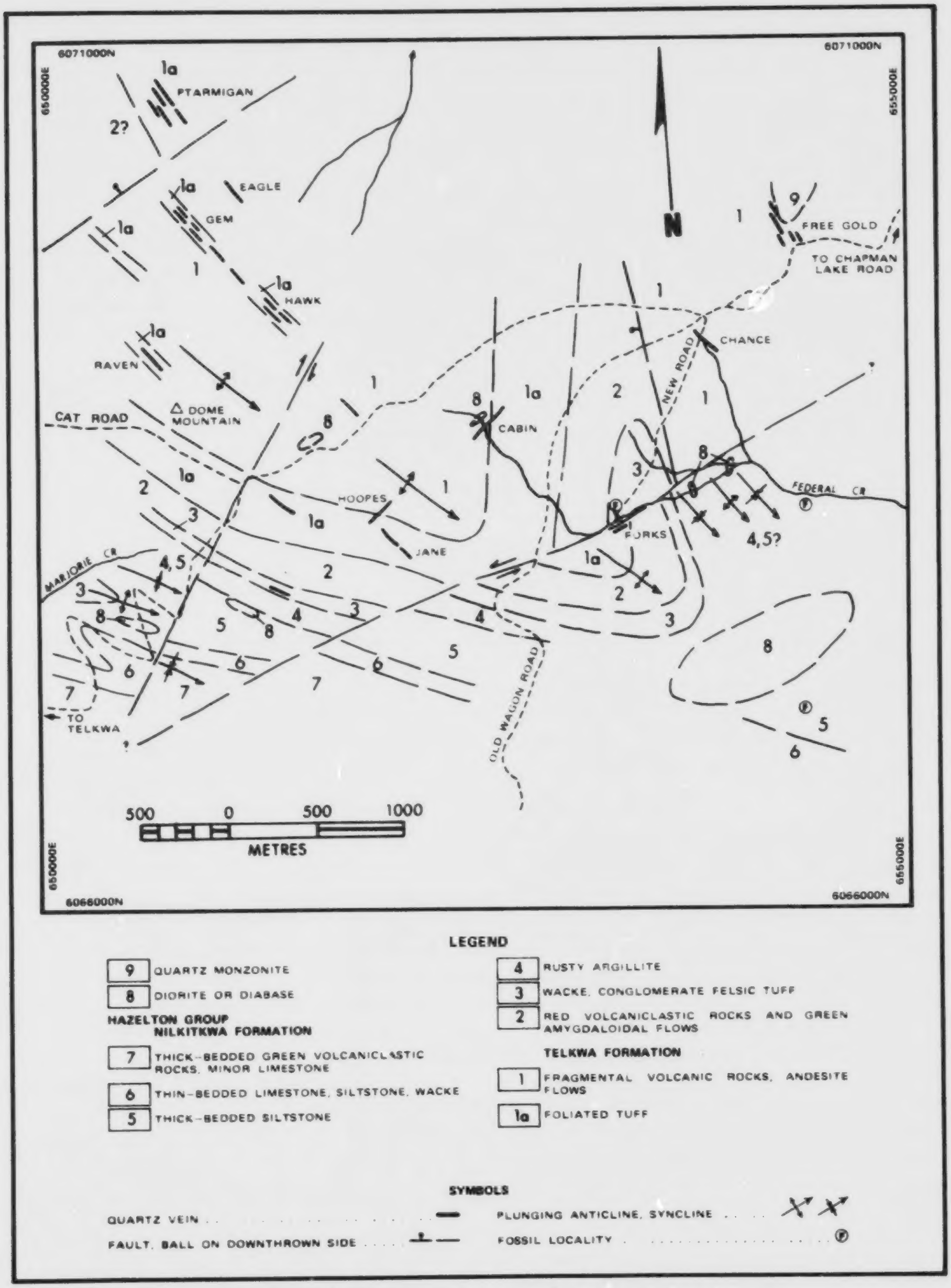

6071000N
6071000N
650000E
655000E
1a
PTARMIGAN
2?
EAGLE
1a
GEM
1a
1
1a
HAWK
1a
RAVEN
DOME MOUNTAIN
CAT ROAD
N
1
9
FREE GOLD
TO CHAPMAN LAKE ROAD
1
CHANCE
NEW ROAD
1
1a
2
8
CABIN
8
1
1a
2
3
HOOPES
1
1a
JANE
FORKS
FEDERAL CR
4,5?
MARJORIE CR
4,5
3
8
1a
2
5
8
4
3
4
3
8
6
6
5
7
7
6
7
TO TELKWA
OLD WAGON ROAD
5
6
500
0
500
1000
METRES
650000E
655000E
6066000N
6066000N
LEGEND
9 QUARTZ MONZONITE
8 DIORITE OR DIABASE
HAZELTON GROUP
NILKITKWA FORMATION
7 THICK-BEDDED GREEN VOLCANICLASTIC ROCKS, MINOR LIMESTONE
6 THIN-BEDDED LIMESTONE, SILTSTONE, WACKE
5 THICK-BEDDED SILTSTONE
4 RUSTY ARGILLITE
3 WACKE, CONGLOMERATE FELSIC TUFF
2 RED VOLCANICLASTIC ROCKS AND GREEN AMYGDALOIDAL FLOWS
TELKWA FORMATION
1 FRAGMENTAL VOLCANIC ROCKS, ANDESITE FLOWS
1a FOLIATED TUFF
SYMBOLS
QUARTZ VEIN
FAULT, BALL ON DOWNTHROWN SIDE
PLUNGING ANTICLINE, SYNCLINE
FOSSIL LOCALITY

Figure 65. Preliminary geology of the Dome Mountain gold camp.

Ingray Yellowknife Mines Limited and in 1951 Lake Surprise Mines Limited reopened the underground workings. In 1967 to 1969 and 1972 to 1973, Cordilleran Engineering and Amoco Canada Petroleum Company respectively examined the Free Gold property as a possible porphyry copper prospect. In 1979 and 1980, E. Messich and M. Kryger built a road connecting the Free Gold property to the Chapman Lake logging road and extended the underground workings. From 1981 to 1983, Reako Explorations Limited and Panther Mines Limited completed additional underground development and surface trenching. During the 1984 field season, all the properties on Dome Mountain with the exception of the Free Gold were under option to Noranda Exploration Company, Limited. Noranda did soil sampling on a newly cut grid and constructed a road to the Forks showing. Drill sites were established but no drilling was done.

REGIONAL GEOLOGIC SETTING

The Dome Mountain area is underlain by subaerial to submarine volcanic, volcaniclastic and sedimentary rocks of the Hazelton Group (Fig. 64). The Hazelton Group is an island-arc assemblage that was deposited in the northwest trending Hazelton Trough between Early Jurassic and Middle Jurassic time. Tipper and Richards (1976) divide the Hazelton Group into three major formations in the Smithers map-area (93L). These are the Late Sinemurian to Early Pliensbachian Telkwa Formation, the Early Pliensbachian to Middle Toarcian Nilkitkwa Formation, and the Middle Toarcian to Lower Callovian Smithers Formation.

The Telkwa Formation, which is comprised of subaerial and submarine pyroclastic and flow rocks with lesser intercalated sedimentary rocks, is the thickest and most extensive formation of the Hazelton Group. The mixed subaerial to submarine Babine Shelf facies of the Telkwa Formation, which separates the subaerial Howson facies to the west and the submarine Kotsine facies to the east, underlies the Babine Range (Tipper and Richards, 1976).

The Nilkitkwa Formation conformably to disconformably overlies the Telkwa Formation. West of Dome Mountain it is comprised of predominantly Toarcian red pyroclastic rocks; to the east it includes Early Pleinsbachian to Middle Toarcian marine sedimentary rocks with intercalated rhyolite to basalt flows.

In the Babine Range, the Smithers Formation disconformably overlies the Nilkitkwa Formation; it is predominantly Bajocian in age. It is comprised of fossiliferous sandstone and siltstone with lesser intercalated felsic tuff. As far as is known, the Smithers Formation does not occur within the area of Figure 65.

DOME MOUNTAIN GEOLOGY

The core of Dome Mountain is underlain by a large southwest-verging, southeast-plunging anticlinal structure that has been cut by northeast

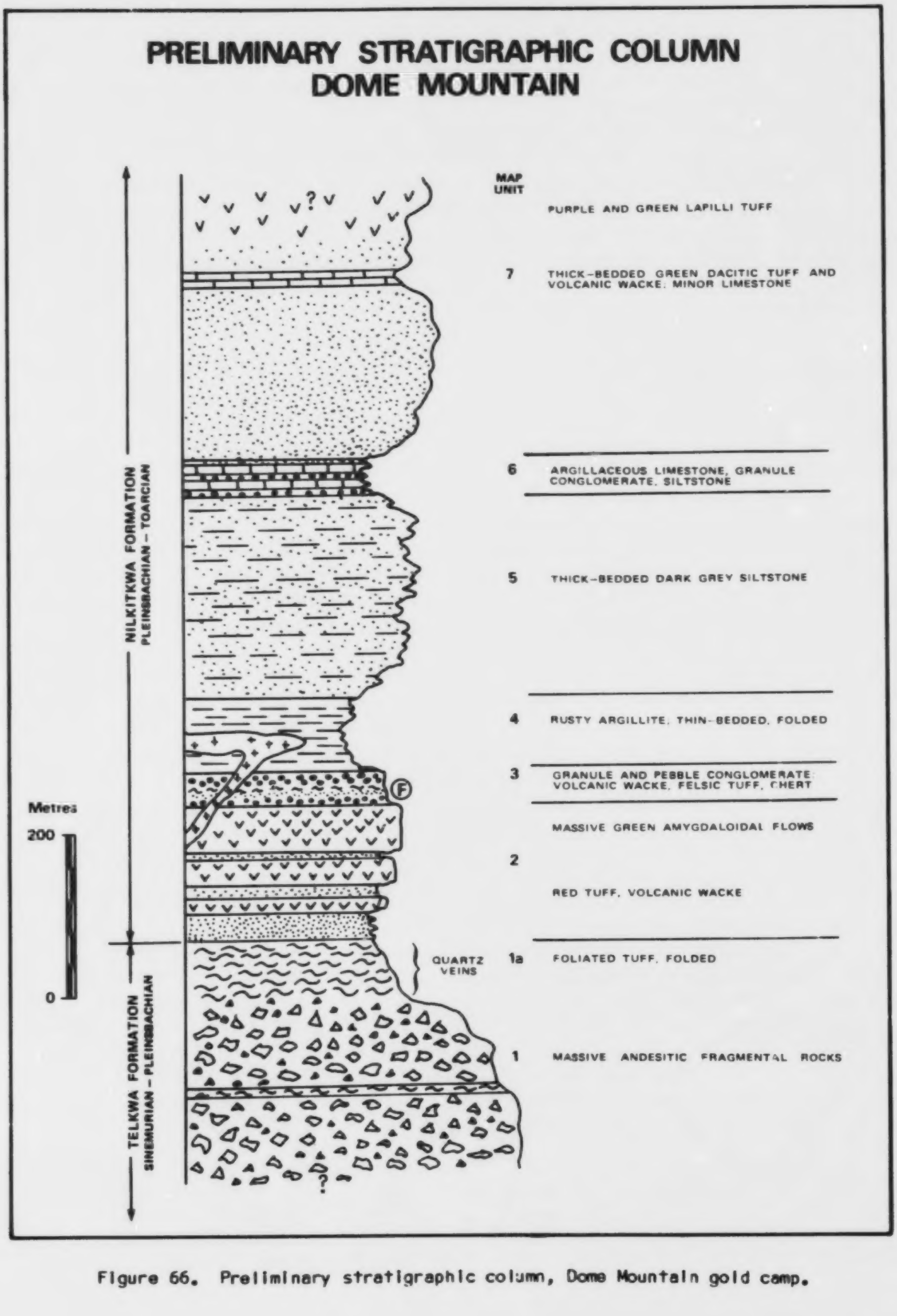

PRELIMINARY STRATIGRAPHIC COLUMN
DOME MOUNTAIN
MAP UNIT
PURPLE AND GREEN LAPILLI TUFF
7
THICK-BEDDED GREEN DACITIC TUFF AND VOLCANIC WACKE, MINOR LIMESTONE
6
ARGILLACEOUS LIMESTONE, GRANULE CONGLOMERATE, SILTSTONE
5
THICK-BEDDED DARK GREY SILTSTONE
4
RUSTY ARGILLITE, THIN-BEDDED, FOLDED
3
GRANULE AND PEBBLE CONGLOMERATE, VOLCANIC WACKE, FELSIC TUFF, CHERT
F
MASSIVE GREEN AMYGDALOIDAL FLOWS
2
RED TUFF, VOLCANIC WACKE
QUARTZ VEINS
1a
FOLIATED TUFF, FOLDED
1
MASSIVE ANDESITIC FRAGMENTAL ROCKS
NILKITKWA FORMATION
PLEINSBACHIAN – TOARCIAN
TELKWA FORMATION
SINEMURIAN – PLEINSBACHIAN
Metres
200
0
?

Figure 66. Preliminary stratigraphic column, Dome Mountain gold camp.

and northwest-trending high angle faults (Fig. 65). The oldest rocks are well exposed on the crest of the mountain and a good stratigraphic section is exposed on the south slope. A preliminary stratigraphic column (Fig. 66) has been established on the basis of this section. Seven major map units are recognized. Going up section these are: (1) fragmental volcanic unit (+1000 metres?); (2) red volcaniclastic-green flow unit (150-200 metres); (3) volcanic wacke-conglomerate-felsic tuff unit (20-50 metres); (4) rusty argillite or shale unit (50-100 metres); (5) dark grey siltstone unit (250-300 metres); (6) thin-bedded limestone-siltstone-wacke unit (50-100 metres); and (7) greenish grey massive volcaniclastic unit (+500 metres). The ages of these units and their correlations with Hazelton Group formations are not well established. Limestone samples are currently being processed for microfossils.

Several small plugs or dykes of diabase or diorite intrude the Hazelton Group on Dome Mountain; a stock of quartz porphyry or quartz monzonite is exposed near the Free-gold showing.

HAZELTON GROUP

Telkwa Formation

Fragmental volcanic unit (1)

A chaotic assemblage of coarse-grained agglomerate, tuff-breccia and lapilli tuff with lesser intercalations of lithic, crystal and ash tuff, and volcanic derived sedimentary rocks crops out on Dome Mountain. These rocks are purple, mauve, green and grey in colour. Clasts range from less than 1 centimetre to 40 centimetres in diameter and are typically comprised of porphyritic andesite or crystal tuff. The matrix also contains abundant crystal and lithic fragments. In places the clasts are flattened parallel to bedding. Beds comprised of large rounded bombs up to 30 centimetres in diameter floating in a fine-grained ash matrix are common. Finer grained tuff beds within the unit are strongly foliated subparallel to bedding. The fragmental volcanic unit is believed to correlate with the Babine shelf facies of the Telkwa Formation as described by Tipper and Richards (1976).

Nilkitkwa Formation

Red volcaniclastic - green flow unit (2)

A distinctive unit of red volcaniclastic rocks and green to mauve amygdaloidal flows overlies the fragmental volcanic unit that forms the core of Dome Mountain. This unit is well exposed on the south slope of Dome Mountain and in Federal Creek above and below the Forks showing. Near the crest of Dome Mountain the basal part of the unit is comprised of thin-bedded brick red lithic tuff, crystal tuff, volcanic wacke, and granule conglomerate that is locally cross-bedded. Interlayered lime green, amygdaloidal basalt or andesite increases in abundance up section and comprises the upper part of the unit. Outcrops of this unit in Federal Creek are thicker bedded and have less reworked volcanic detritus than those near the crest of Dome Mountain, suggesting a facies variation to the east. Here the volcanic part of the unit varies from mauve to green in colour but still contains conspicuous chlorite-filled amygdules and vesicles.

The red volcaniclastic-green flow unit is probably the basal member of the Nilkitkwa Formation on Dome Mountain. It represents a period of exposure and erosion of the Telkwa Formation and deposition of subaerial pyroclastic rocks. This apparently was followed by a marine transgression and deposition of green submarine basaltic flows.

Tipper and Richards (1976) describe a red tuff member of the Nilkitkwa Formation which is lithologically similar to the basal part of the red volcaniclastic-green flow unit on Dome Mountain. However this red tuff member is Toarcian in age and overlies a marine sedimentary unit of the Nilkitkwa Formation. If this relationship is correct then the red volcaniclastic-green flow unit occurs lower down in the section and does not correlate with the red tuff member. Additional evidence supporting this conclusion is the fact that sedimentary rocks that apparently overlie the red volcaniclastic-green flow unit near the Forks showing are reported to contain a Late Pliensbachian pelecypod (Myers, personal communication).

Volcanic wacke - conglomerate - felsic tuff unit (3)

A thin unit of brown to buff weathering volcanic wacke, siltstone, granule to pebble conglomerate and fine-grained felsic tuffs or flows overlies green amygdaloidal flows of the red volcaniclastic-green flow unit. The finer-grained clastic rocks typically have a slaty cleavage and contain small angular clasts in a silty matrix. As mentioned above, the unit contains poorly preserved Pliensbachian pelecypods. Adjacent to the Forks shaft on the south slope of Dome Mountain and the north bank of Federal Creek, this unit is pervasively altered and has disseminated pyrite and broken quartz stringers suggestive of an early hydrothermal (exhalative?) event.

Rusty argillite unit (4)

A recessive, poorly exposed unit of thin-bedded, rusty weathering silty argillite occupies a small depression between the main part of Dome Mountain and its southern spur. The unit typically has a well-developed slaty cleavage and tight small scale fold structures; it lacks carbonate and contains ubiquitous disseminated pyrite. Exploration companies have dug several bulldozer trenches across the unit near the crest of the Dome Mountain ridge but no significant economic mineral concentration has been discovered.

Thick-bedded siltstone unit (5)

Up to 300 metres of monotonous, medium to thick-bedded, dark grey siltstone overlies the rusty argillite unit. This unit, which is relatively resistant forms the backbone of the south spur of Dome Mountain. The siltstone has a slaty cleavage in places. Lithologically similar rocks that crop out in Federal Creek, below the Forks showing, are probably part of this unit.

Thin-bedded limestone-siltstone-wacke unit (6)

The thick-bedded siltstone unit grades up section into a relatively thin unit of well-bedded dark grey argillaceous limestone, limy siltstone, and wacke with lesser intercalations of pebble conglomerate and chert. These rocks crop out near the southeast end of Dome Mountain ridge, and in the lower road cuts on the southwest slope above Marjorie Creek. The limestone beds weather in positive relief producing a ribbed appearance on weathered surfaces. Lithologically similar rocks crop out in the lower part of Federal Creek. However, L'Orsa (1982) reports that these rocks contain a poorly preserved ammonite that Tipper identified as probably Sinemurian in age. Therefore, correlation of these rocks with the Nilkitkwa Formation is suspect; they may be a sedimentary member of the Telkwa Formation. A small outcrop of similar lithology occurs in the clear cut southeast of Dome Mountain.

Green thick-bedded vlcaniclastic unit (7)

The south slope of Dome Mountain is underlain by massive, light green, calcareous crystal tuff or volcanic wacke with rare intercalations of argillaceous limestone and shaly siltstone. The unit, which is estimated to be at least 500 metres thick, grades up section into a mixed assemblage of mauve, red, and green lithic, crystal and lapilli tuffs. These rocks may correlate with the red tuff member of the Nilkitkwa Formation. Tipper and Richards (1976) describe similar rocks in the upper part of the Nilkitkwa Formation northeast of Dome Mountain. As far as is known, these are the youngest rocks in the Dome Mountain gold camp.

INTRUSIVE ROCKS

Several small elongate plugs or dykes of fine to medium-grained diorite or diabase intrude the Telkwa and Nilkitkwa Formations on Dome Mountain. The largest intrusion is exposed on the lower southeast slope, just south of Federal Creek. These mafic-rich intrusions cause the prominent aeromagnetic anomaly that is centred on Dome Mountain. The dioritic intrusions are probably Jurassic in age and, therefore, members of the Topley Intrusions.

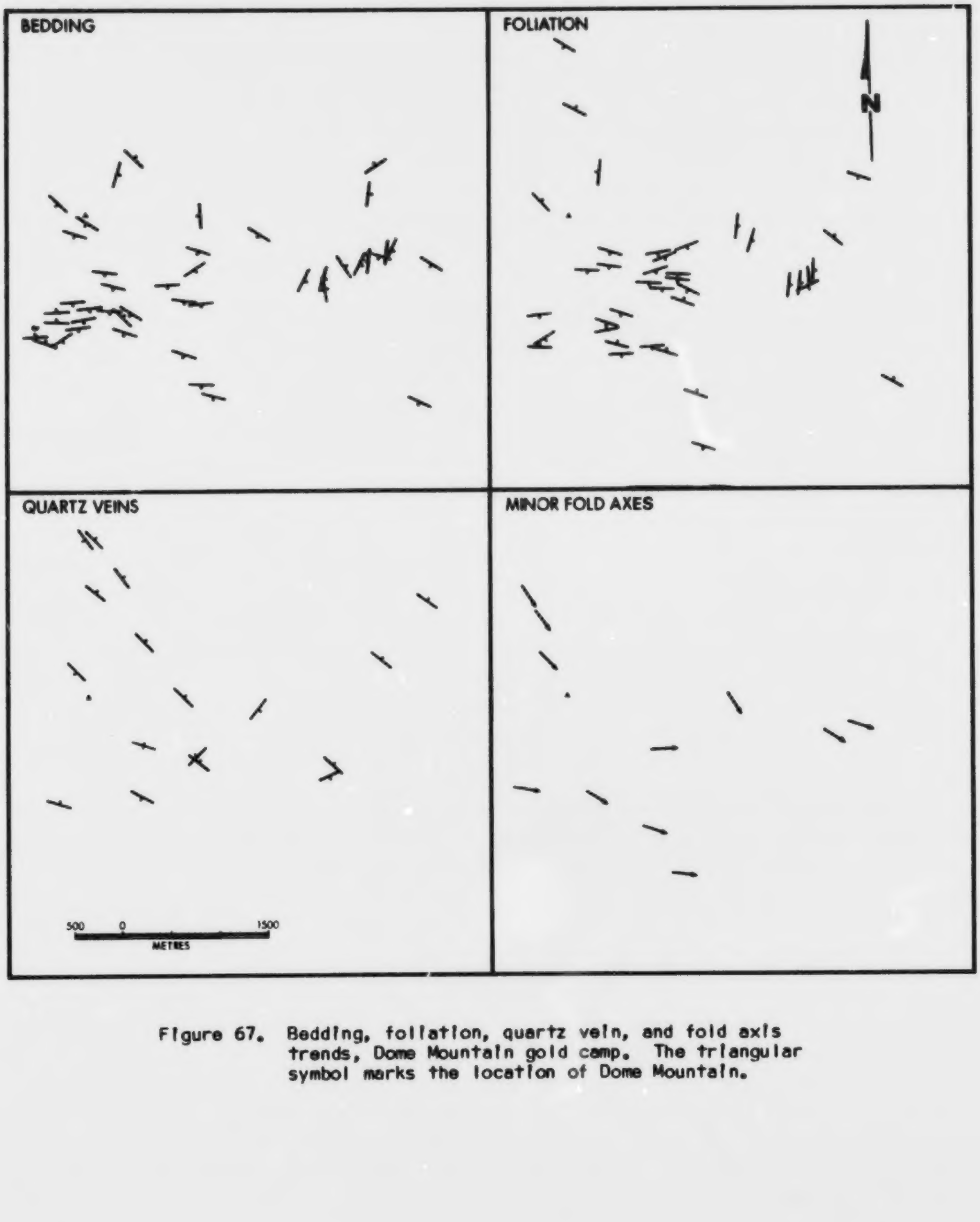

BEDDING
FOLIATION
N
QUARTZ VEINS
MINOR FOLD AXES
500
0
1500
METRES

Figure 67. Bedding, foliation, quartz vein, and fold axis trends, Dome Mountain gold camp. The triangular symbol marks the location of Dome Mountain.

Outcrops of altered quartz porphyry and porphyritic quartz monzonite contain quartz vein stockworks that occur east of the Free Gold veins. These intrusive rocks were the target of porphyry copper exploration between 1967 and 1972.

STRUCTURE

Dome Mountain is underlain by a large anticlinal structure that plunges to the southeast (Fig. 65). Evidence supporting this conclusion includes the repetition of stratigraphic units on either side of Dome Mountain, the attitude of minor fold axes which plunge gently to the southeast and east (Fig. 67), and the general change from southwest to southeast of dips for bedding and foliation about a southeast-trending axial trace (Fig. 67). The southwest limbs of minor folds generally dip steeply to the southwest or northeast; the northeast limbs typically dip gently to the northeast. This suggests the large scale fold structures are asymmetric and verge to the southwest.

Fine-grained tuffaceous and sedimentary rocks on Dome Mountain have a well-developed, early slaty cleavage (S1). This cleavage, which is subparallel to bedding, is locally folded and cut by a weak crenulation cleavage (S2) that is axial planar to the major fold structures. Early quartz veins, which both parallel and cross-cut the slaty cleavage, have been broken and offset by the crenulation cleavage (Plate VII). Locally quartz veins, that parallel the slaty cleavage, are folded (Plate VIII); contained sulphides are broken and recrystallized as a result of this folding. Massive fragmental rocks of the Telkwa Formation generally have a poorly defined fracture cleavage that roughly parallels the crenulation cleavage.

Joint trends on Dome Mountain are shown on Figures 67 and 68. The most prominent joint set dips steeply to the northwest. This trend is roughly perpendicular to the major fold axes. These joints also parallel prominent airphoto linears and several major high angle faults which offset the stratigraphy (Fig. 65).

MINERAL OCCURRENCES

The location of quartz veins on Dome Mountain is shown on Figures 65 and 67. Characteristics of the veins are summarized in Table 1. Most of the veins trend northwest and dip steeply to the northeast or southwest; the Hoopes and Cabin veins trend northeast. The majority of veins are in foliated and altered tuff, near the upper contact of the Telkwa Formation. The Free Gold veins are a notable exception; they are hosted by massive andesite. The stratigraphic position of these rocks is uncertain. These veins both parallel and cut the foliation. The quartz veins vary from a few centimetres up to 3 metres in width. Some veins are lenticular and locally folded and brecciated; others have

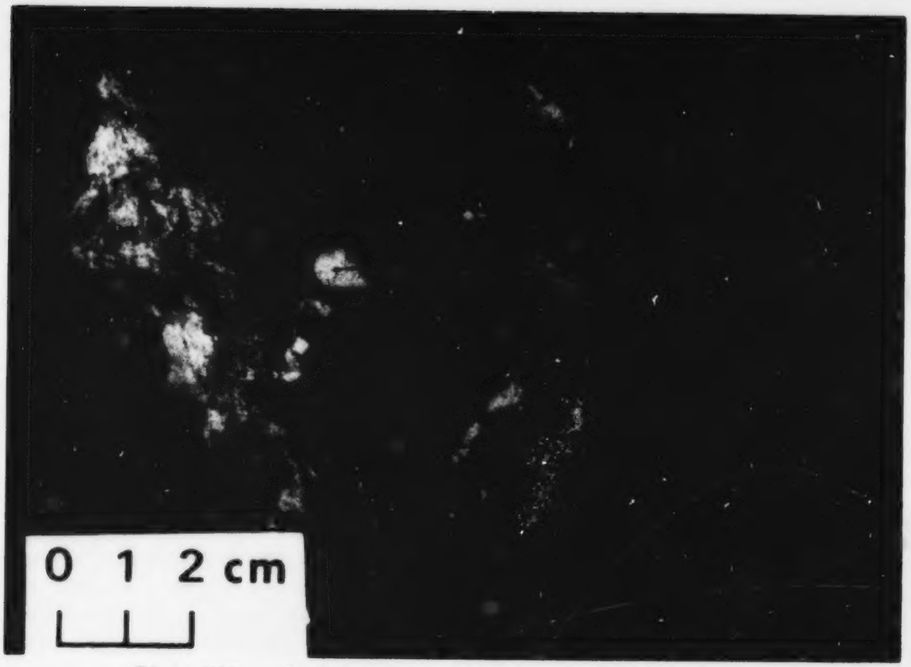


Plate VII. Foliated and folded quartz veins in the wallrock of the Cabin vein.

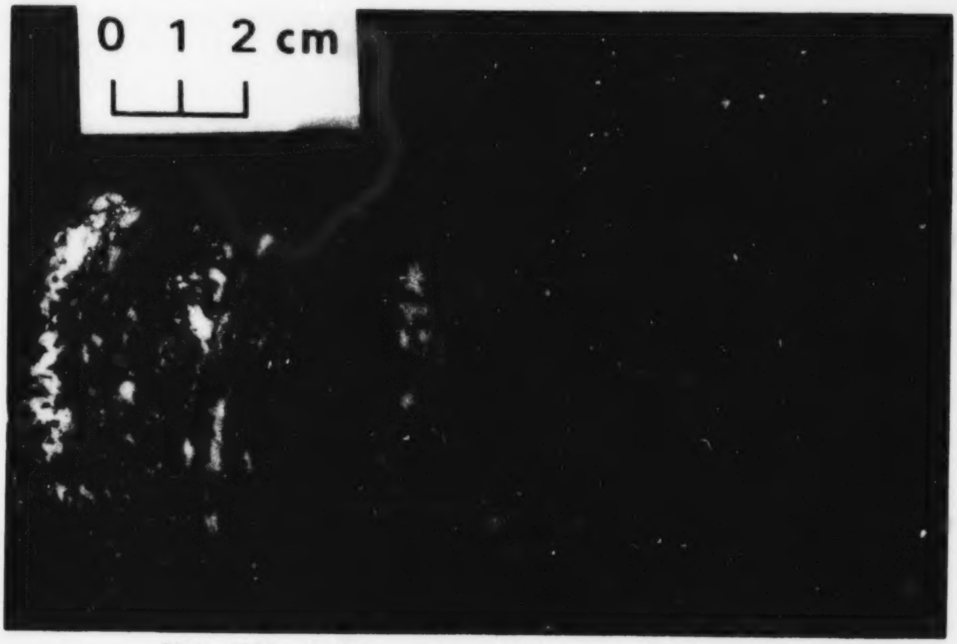


Plate VIII. Folded and brecciated quartz, Raven vein.

considerable lateral continuity with little variation in attitude and do not appear to be deformed. Intensity of wallrock alteration is variable; it is most intense near the Forks and Cabin veins but almost non-existent near the Free Gold veins. Sulphide mineralogy is also variable; pyrite, pyrite-chalcopyrite, pyrite-chalcopyrite-galena, pyrite-galena-sphalerite, and pyrite-arsenopyrite assemblages are present (Table 1).

TABLE 1
DOME MONTAIN QUARTZ VEINS

No.	Name	Mineralogy	Host Rocks	Alteration
1.	Forks	Py, Gl, Sp, (As)	Foliated tuffs	Intense
2.	Free Gold	Py, Sp, Gl, (Cp)	Green andesite	None or minor
3.	Cabin	Py, Gl, (Cp, As)	Foliated tuffs	Moderate
4.	Jane	Py, Cp, (Sp, Gl)	Foliated tuffs	Weak to moderate
5.	Hoopes	Py, Cp	Foliated tuffs	Moderate
6.	Hawk	Py	Foliated tuffs	Weak to moderate
7.	Gem	Py, Cp, As, Sp, Gl	Foliated tuffs	Weak to moderate
8.	Eagle	Py	Tuffs	Weak
9.	Ptarmigan	Py, As, Sp, Gl	Foliated tuffs	Weak to moderate
10.	Raven	Py, Cp	Foliated folded tuffs	Weak to moderate
11.	Chance	Py	Foliated tuffs	Moderate to intense

Py = pyrite; Cp = chalcopyrite; Gl = galena; Sp = sphalerite; As = arsenopyrite
minor components in brackets

Forks (Mineral Inventory 93L-22)

Stream deposits now cover the original Forks showing, which is reported to occur in the bed of Federal Creek just below its confluence with a small southern tributary (Minister of Mines, Annual Reports, 1922, 1923, 1924). Tuff outcrops on the banks of Federal Creek, above and below the showing, are pervasively sericite-carbonate-fuchsite altered and foliated, and cut by quartz stringers (Fig. 69). Several short adits were driven into this zone in the early days of exploration but these failed to intersect any major quartz veins. However, subsequent underground development by the Dome Mountain Mining Company in 1923 and 1924 intersected two major quartz veins, one trending northwest and dipping northeast, the other trending northeast (Fig. 69).

In 1923, a three-compartment shaft was sunk to a depth of 32 metres and a 45-metre tunnel driven to the northwest. A 12-metre crosscut intersected a northeast-dipping quartz vein which was then drifted on for approximately 45 metres going southeast. Dome Mountain Mining Company sampled the vein at 1.5-metre intervals over a strike length of 33.5 metres. The sample width, and presumably the vein width, varied from 30 to 150 centimetres. Precious metal values ranged from 1.4 to 75.5 grams per tonne (0.04 to 2.20 ounces per ton) gold and 10.3 to 120 grams per tonne (0.3 to 3.5 ounces per ton) silver. The weighted average of these assays is 15.3 grams per tonne (0.447 ounce per ton) gold and 59.0 grams per tonne (1.72 ounces per ton) silver.

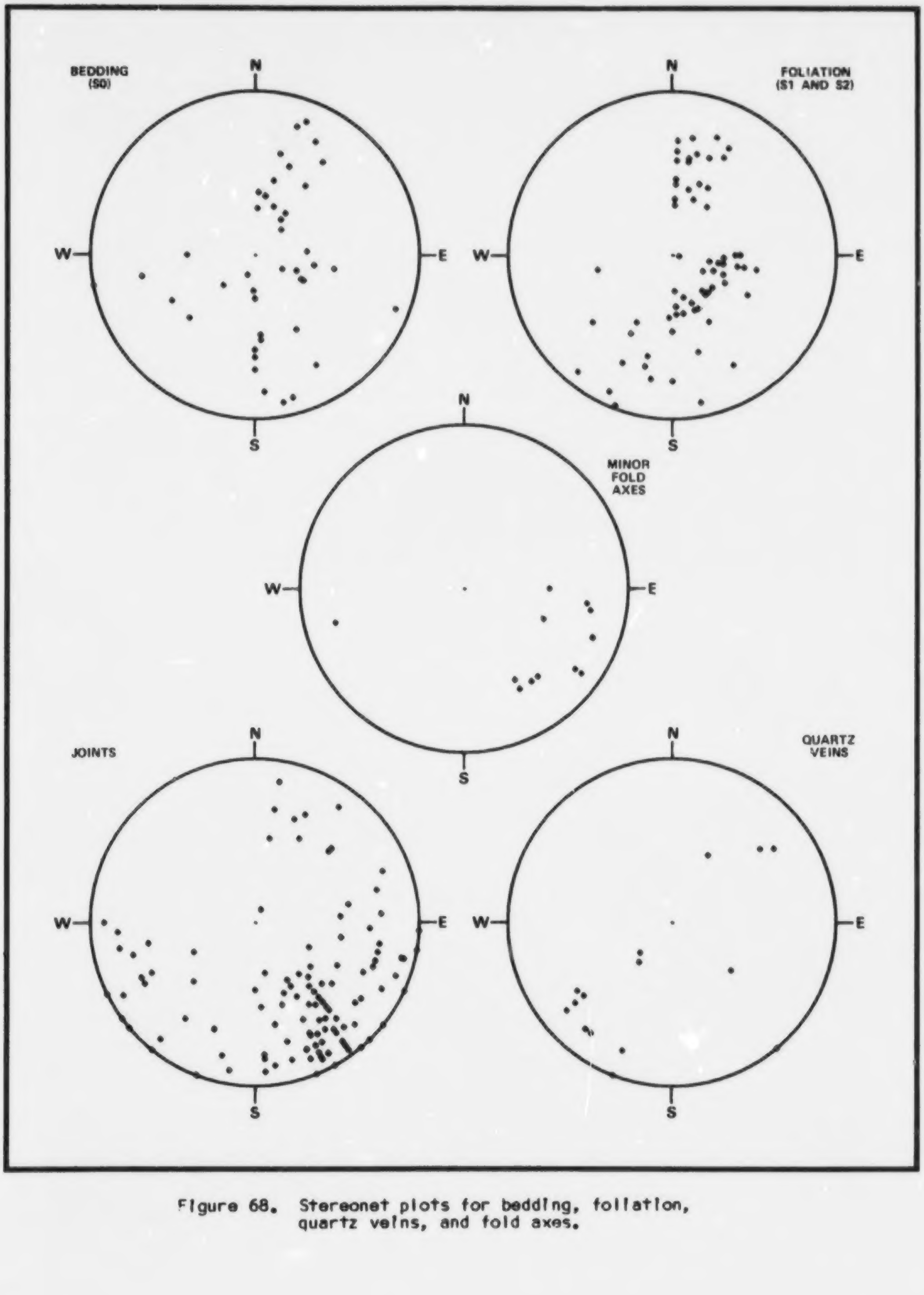


Figure 68. Stereonet plots for bedding, foliation, quartz veins, and fold axes.

The caved portal and winze for a 27-metre-long, southeast-trending adit is located approximately 23 metres west of the Forks shaft (Fig. 69). Approximately 12 metres of drifting and a short winze follow a quartz vein northeast from the end of the adit. Dome Mountain Mining Company sampled the quartz vein at 1.5-metre intervals along the drift and winze. The weighted average for these samples was 42.1 grams per tonne (1.23 ounces per ton) gold and 85.4 grams per tonne (2.49 ounces per ton) silver over approximately 12 metres.

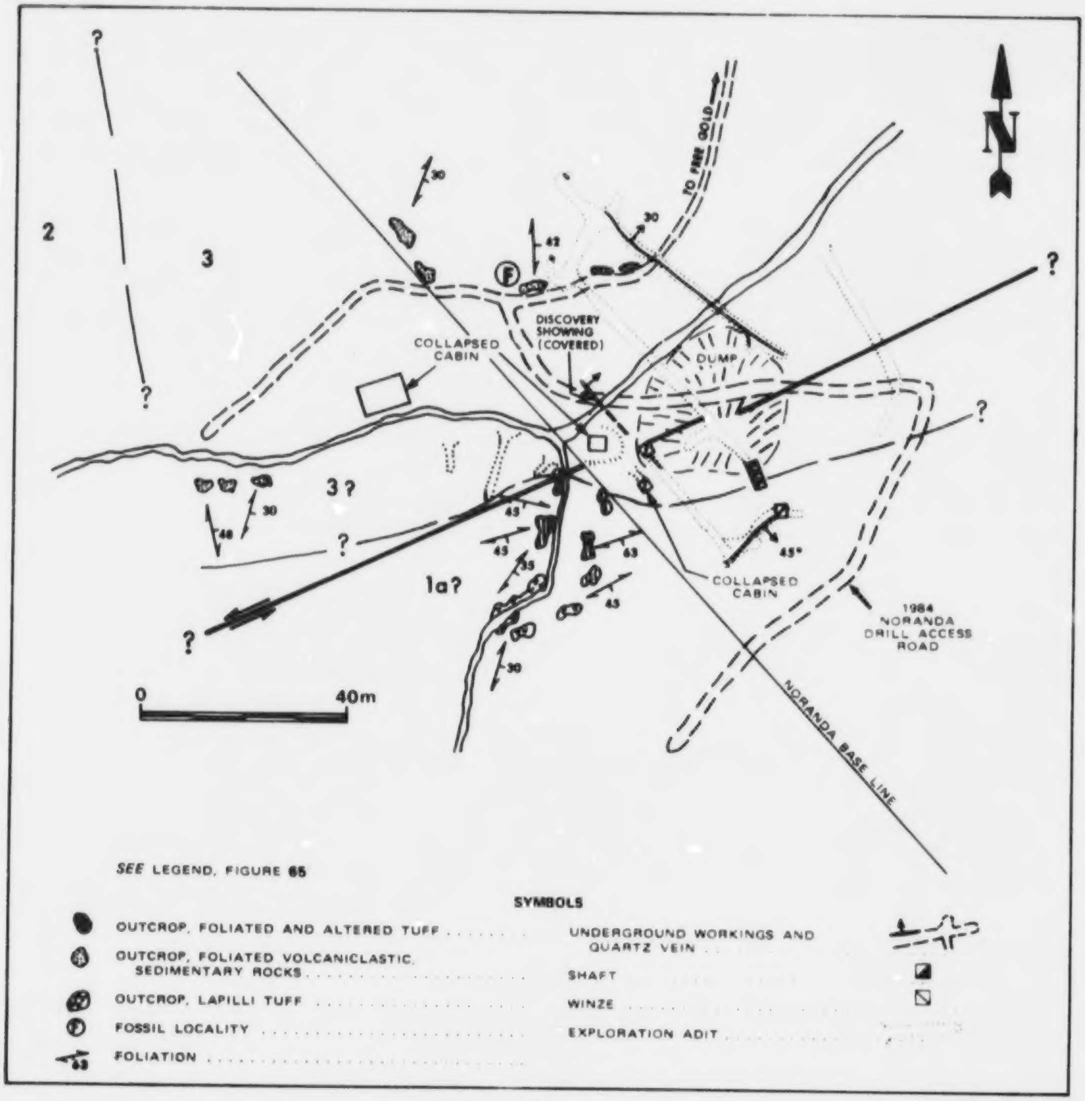

N
TO FREE GOLD
2
3
3 ?
1a?
?
F
DISCOVERY SHOWING (COVERED)
COLLAPSED CABIN
DUMP
COLLAPSED CABIN
1984 NORANDA DRILL ACCESS ROAD
NORANDA BASE LINE
30
42
30
40
30
43
43
55
63
43
45°
30
0
40m
SEE LEGEND, FIGURE 65
SYMBOLS
OUTCROP, FOLIATED AND ALTERED TUFF
OUTCROP, FOLIATED VOLCANICLASTIC, SEDIMENTARY ROCKS
OUTCROP, LAPILLI TUFF
FOSSIL LOCALITY
FOLIATION
63
UNDERGROUND WORKINGS AND QUARTZ VEIN
SHAFT
WINZE
EXPLORATION ADIT

Figure 69. Detailed geology of the Forks vein.

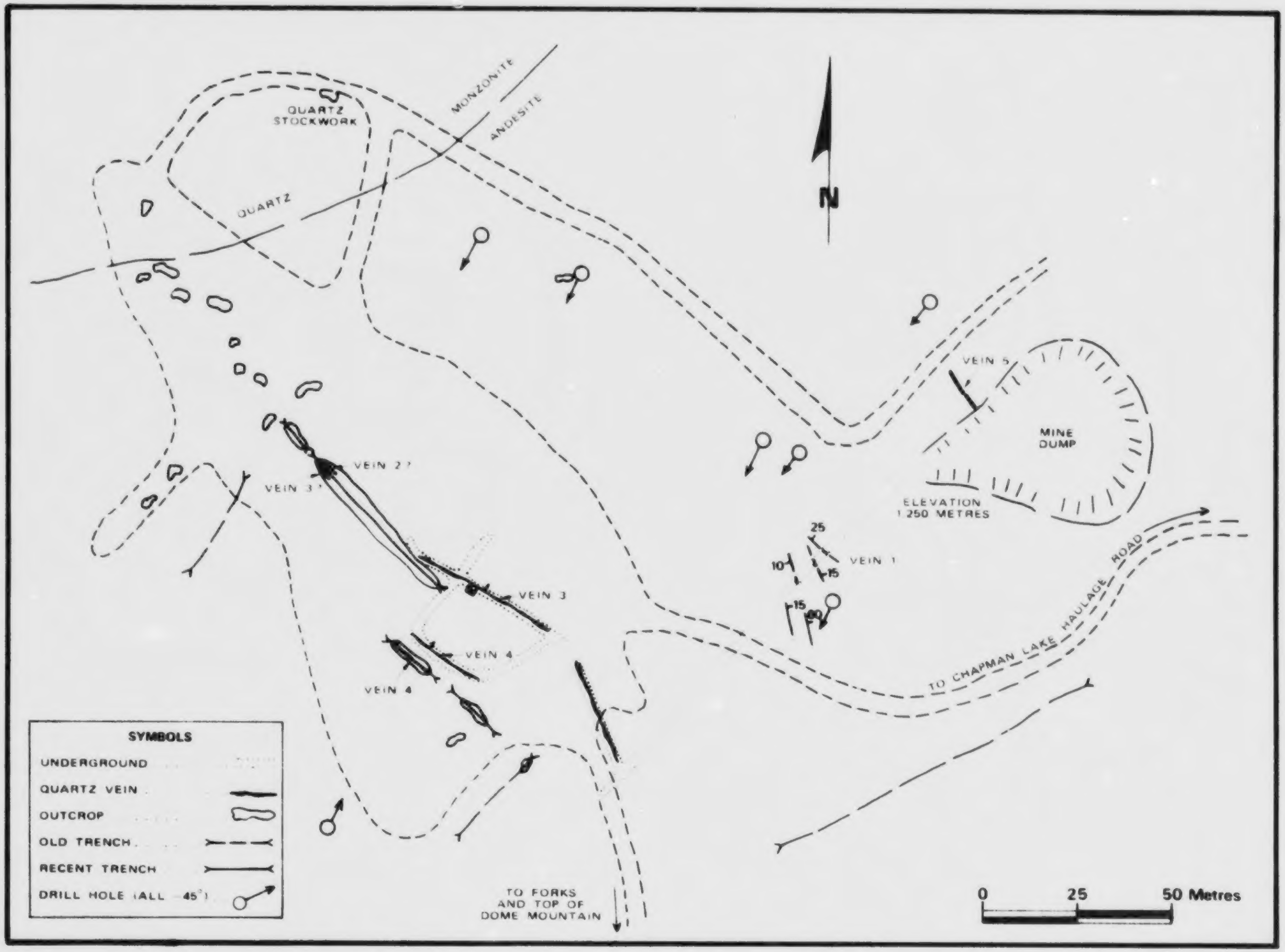

QUARTZ STOCKWORK
QUARTZ
MONZONITE
ANDESITE
N
VEIN 5
MINE DUMP
ELEVATION 1 250 METRES
VEIN 2?
VEIN 3?
25
10
15
15
20
VEIN 1
VEIN 3
VEIN 4
VEIN 4
TO CHAPMAN LAKE HAULAGE ROAD
TO FORKS AND TOP OF DOME MOUNTAIN
SYMBOLS
UNDERGROUND
QUARTZ VEIN
OUTCROP
OLD TRENCH
RECENT TRENCH
DRILL HOLE (ALL −45°)
0
25
50 Metres

Figure 70. Detailed geology of the Free Gold vein.

Free Gold (Mineral Inventory 93L-23)

The Free Gold showings are located on the heavily timbered northeast slope of Dome Mountain, at approximately 1 250 metres elevation. Access is via a good gravel road which leaves the Chapman Lake haulage road at kilometre 69.

Babine Gold Mines Limited was incorporated in 1932 to explore the Free Gold property. Early exploration included hand trenching, surface stripping, and sinking of shallow shafts and pits. In 1933 and 1934, a crosscut adit was driven approximately 110 metres southwest. The number 3 vein was intersected and a 42-metre drift was driven to the northwest (Fig. 70). A crosscut was then driven southwest and approximately 23 metres of drifting was done on the number 4 vein. Additional drifting was done on the number 3 vein from the end of a northeast crosscut (Fig. 70).

Exploration work on the Free Gold property has discovered five major (1 to 5) and many smaller quartz veins. These veins vary from a few centimetres to 2 metres in width. Most of the veins dip steeply northeast; some shallow-dipping veins are also present east of the main showings (Fig. 70). Some of the veins may merge at depth as indicated by converging strike and dip directions.

The Free Gold quartz veins typically contain pyrite with lesser amounts of sphalerite, galena, tetrahedrite, and chalcopyrite. Native gold is rare. Late fault movement along some of the veins has shattered the quartz and attendant sulphide grains. The host andesite is only slightly altered; it does not have the well-defined foliation typical of host rocks for veins higher up on Dome Mountain.

Canada Department of Mines and Resources processed a bulk shipment of 680 pounds in 1938 (*Minister of Mines, B.C.*, Ann. Rept., 1938). This shipment averaged 61 grams per tonne (1.78 ounces per ton) gold, 75 grams per tonne (2.18 ounces per ton) silver, 1.54 per cent lead, 5.87 per cent zinc, 0.15 per cent copper, 0.02 per cent arsenic, and 10.38 per cent sulphur. Polished sections of the ore showed that shattered pyrite grains were veined by successively later sphalerite, tetrahedrite, chalcopyrite, and galena. Minute grains of native gold occur in galena and chalcopyrite microveinlets that cut and heal shattered pyrite. Babine Gold Mines Limited made a further shipment of 2 715 tonnes of high-grade ore to the Prince Rupert smelter in 1940 (*Minister of Mines, B.C.*, Ann. Rept., 1940).

In 1951, Lake Surprise Mines Limited optioned the Free Gold group and did a comprehensive sampling of quartz veins both on the surface and underground. The weighted average of 31 samples collected over 24 metres on the northeast drift of vein number 3 was 27.2 grams per tonne (0.79 ounce per ton) gold, 28.3 grams per tonne (0.83 ounce per ton) silver, and 1.35 per cent zinc; the southwest drift averaged 58.7 grams per tonne

(1.71 ounces per ton) gold, 80.1 grams per tonne (2.35 ounces per ton) silver, 6.1 per cent zinc, and 2.08 per cent lead for 13 samples collected over 12 metres. This vein was also sampled on surface. The average of 40 samples collected over 61 metres was 70.5 grams per tonne (2.07 ounces per ton) gold, 94.1 grams per tonne (2.76 ounces per ton) silver, and 0.81 per cent zinc. Recent operators have apparently mined this part of the vein by an open cut (Fig. 70). Twenty-four samples collected over 27 metres in the drift on the number 4 vein averaged 20 grams per tonne (0.58 ounce per ton) gold, 62.9 grams per tonne (1.8 ounces per ton) silver, and 1.67 per cent zinc. This work showed the erratic nature of metal concentrations within the quartz veins. Gold assays ranged from 391 grams per tonne (11.4 ounces per ton) to trace.

The Free Gold property was reexamined by Cordilleran Engineering and Amoco Canada Petroleum Company in 1967-1969 and 1972-1973 respectively. This work focused on a possible porphyry copper deposit associated with the quartz monzonite intrusion located north of the main quartz vein occurrences.

Panther Mines Limited optioned the Free Gold property from Lorne Warren in 1980 and subsequently entered into a joint venture with Reako Explorations Limited. The property was drilled in 1981. Drill hole locations and quartz vein intersections are shown on Figure 70. It is difficult to correlate the drill intersections with known surface and underground vein occurrences further illustrating the unpredictable nature of quartz veins on the property. This complexity is probably due to faulting.

Cabin

The Cabin vein crops out near the head waters of Federal Creek. Here it is approximately 3 metres wide and strikes northeast. The vein contains abundant pyrite with lesser arsenopyrite and galena. Gold values are reported to be relatively low (*Minister of Mines, B.C.*, Ann. Rept., 1922). The quartz vein is bounded by a narrow zone of strongly altered and foliated rock that cuts the regional foliation. In 1923, Dome Mountain Mining Company drove a crosscut north; it intersected the vein at 107 metres. The vein was followed by short drifts to the northeast and southwest. Gold values along the drifts ranged from 0.68 to 20.9 grams per tonne (0.02 to 0.61 ounce per ton) with up to 181.8 grams per tonne (5.3 ounces per ton) silver (Hilchey, 1963).

Jane

The Jane vein is located on the southwest slope of Dome Mountain ridge (Fig. 65). Several short crosscut trenches expose this narrow, northwest-trending vein over a strike length of approximately 150 metres. The quartz vein occurs within a zone of strongly foliated tuffs of the Telkwa

Formation. There is a narrow zone of sericite alteration along the vein margins. The vein contains variable amounts of shattered pyrite and chalcopyrite.

In 1924, the Dome Mountain Mining Company drove a 75-metre-long drift adit on the Jane vein. Company plans show that the vein varies from 30 to 130 centimetres in width; it dips steeply southwest at the portal and moderately northeast at the end of the drift. The best grade material occurs near the portal where the vein averages 68.6 grams per tonne (2.0 ounces per ton) gold and 140.6 grams per tonne (4.1 ounces per ton) silver over a distance of 1.5 metres. From 26 to 41 metres in from the portal the vein averages 6.2 grams per tonne (0.18 ounce per ton) gold with low silver values. Ten samples collected over the last 14.6 metres of the drift had gold and silver values ranging from 1.0 to 16.0 grams per tonne (0.02 to 0.47 ounce per ton) and 27.3 to 1 374.2 grams per tonne (0.8 to 40.3 ounces per ton) respectively. Sample from the remainder of the drift returned low gold and silver values.

The Dome Mountain Mining Company also sunk a shaft a short distance southeast of the portal of the Jane vein. The vein in this shaft is reported to be relatively wide and high grade (*Minister of Mines, B.C.*, Ann. Rept., 1922); it is probably an extension of the Jane vein.

Hoopes

The Hoopes vein is located approximately 215 metres northwest of the portal of the Jane vein. Several trenches have been cut across the vein which appears to trend northeast. The vein is not well enough exposed to determine its exact attitude and thickness. In one trench a steeply dipping quartz vein with abundant pyrite and lesser chalcopyrite is exposed. An adjacent trench exposes a 20-metre-wide zone of pyrite, with lesser sphalerite and galena, in a quartz and albite-healed breccia that may be relatively flat lying. The Hoopes vein, like the Jane vein, occurs within a zone of strongly foliated tuff that overlies massive agglomerate. The vein and breccia zone appear to crosscut the foliation.

A sample collected across 1 metre of the vein is reported to have contained gold and silver values of 43.6 and 171.5 grams per tonne (1.28 and 5.0 ounces per ton) respectively (*Minister of Mines, B.C.*, Ann. Rept., 1922).

Hawk

Trenches on the east slope of Dome Mountain cut across several 20 to 30-centimetre-wide, steeply northeast-dipping quartz veins. Here, the host rocks have a well-developed foliation or slaty cleavage which dips moderately to the northeast. The Hawk veins contain mainly shattered pyrite. Gaul (1922) reports that a well-mineralized sample collected from one of the veins contained 44.6 grams per tonne (1.3 ounces per ton) gold and 343 grams per tonne (10 ounces per ton) silver.

Gem

Prospectors have exposed up to four parallel quartz veins in hand-dug pits and trenches. These workings are located approximately 750 metres along strike from the Hawk veins. The Gem veins dip moderately to the northeast to steeply southwest. The host rocks are medium to thick-bedded tuffs of the Telkwa Formation that dip moderately northeast. There is only weak to moderate foliation and wallrock alteration associated with the Gem veins. The veins contain shattered pyrite and lesser chalcopyrite, arsenopyrite, sphalerite, and galena. Gaul (1922) reports a sample collected across 61 centimetres of the main vein assayed 87.8 grams per tonne (2.56 ounces per ton) gold and 190.7 grams per tonne (5.56 ounces per ton) silver.

Eagle

The Eagle vein is located approximately 275 metres northeast of the Gem veins. A small trench has been dug on the poorly exposed quartz vein. The vein is approximately 20 centimetres wide and dips steeply northeast. A sample collectd by Gaul (1922) across 20 centimetres assayed 38.4 grams per tonne (1.12 ounces per ton) gold and 24 grams per tonne (0.7 ounce per ton) silver.

Ptarmigan

The Ptarmigan veins are located 500 metres northwest of the Eagle vein, on the forest-covered north slope of Dome Mountain. Prospectors have dug several pits and crosscutting trenches in the shallow overburden, exposing at least four parallel quartz veins. The veins are up to 75 centimetres wide; they dip steeply southwest or northeast. On surface they contain pyrite and arsenopyrite-rich bands. Underground, the No. 2 vein is reported to contain lenses of galena, pyrite, and sphalerite. The host rocks are strongly foliated adjacent to the veins but not strongly altered.

In 1924, the Dome Mountain Mining Company drove a 115-metre tunnel to explore the Ptarmigan No. 2 vein. Underground sampling showed the vein to be relatively low grade; the maximum assay reported was 13.7 grams per tonne (0.4 ounce per ton) gold. These results were disappointing because samples from trenches along the vein contained good gold and silver values.

Raven

The Raven vein is located on a northwest-facing slope near the top of Dome Mountain (Fig. 65). Early prospectors drove two short adits on the vein. The vein is well exposed at the back of the upper adit, where it is 20 centimetres wide and contains abundant shattered pyrite and chalcopyrite. The host rocks are strongly foliated tuffs that have subsequently been folded. The vein is conformable to the foliation and has also been folded (Plate VIII). Gold values are reported to be around 34 grams per tonne (1 ounce per ton) (*Minister of Mines, B.C.*, Ann. Rept., 1922).

Chance

The Chance vein is located in the bed of Camp creek, a small southeast-flowing tributary of Federal Creek. It is approximately 750 metres southwest of the Free Gold veins. The quartz vein is approximately 120 centimetres wide and dips steeply northeast; it contains coarse-grained pyrite. The wallrocks are foliated and altered tuffs. The vein is reported to contain "fair" gold values (*Minister of Mines, B.C.*, Ann. Rept., 1923).

DISCUSSION

All of the quartz veins on Dome Mountain, with the exception of the Free Gold veins, are hosted by foliated, fine-grained volcaniclastic rocks. The foliation is essentially a slaty cleavage that probably developed by movement along these less competent beds during the early stages of folding. Many of the quartz veins were probably formed at this time, then were folded and broken as the host rocks were further deformed. This conclusion is supported by the folded nature of many of the quartz veins and the shattered nature of their contained sulphide minerals. Some remobilization of earlier quartz veins may also have taken place during the folding. Post-folding quartz veins are also present but these are usually narrow and barren.

What was the source of the fluids that produced the gold and silver-bearing veins of the Dome Mountain gold camp? Two possibilities are:

(1) The veins are related to buried intrusive bodies which were emplaced during the early stages of folding. The magmatic fluids preferentially moved along the more permeable foliated tuff beds.

(2) The veins were produced by heating and remobilization of low temperature components of a thick volcanic pile during folding. The fluids migrated upward into foliated tuff beds near the top of the volcanic pile.

The first possibility is favoured because of the strong aeromagnetic anomaly associated with Dome Mountain. This anomaly suggests that a buried intrusive body occupies the core of the mountain. This postulated intrusive may be dioritic in composition, as indicated by several small plugs and dykes that occur about the mountain. Also, the intensity of hydrothermal alteration associated with some of the veins suggests the fluids were quite hot and reactive, which is consistent with a magmatic source. Variations in sulphide assemblages in the veins are probably related to depth of exposure and distance from the inferred heat source. In terms of the epithermal model, the veins on Dome Mountain would be fairly deep and at the overlap between the precious metal and base metal zones. A genetic model for the Dome Mountain gold camp is presented on Figure 71.

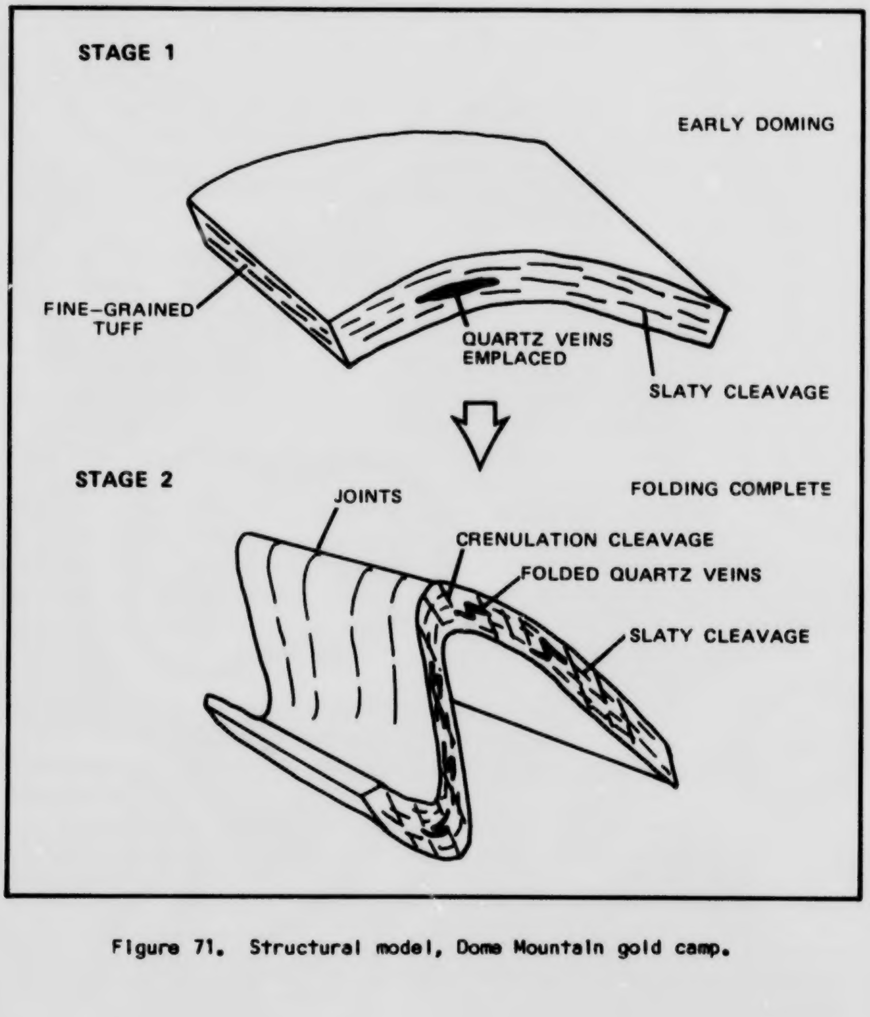

STAGE 1
EARLY DOMING
FINE-GRAINED TUFF
QUARTZ VEINS EMPLACED
SLATY CLEAVAGE
STAGE 2
FOLDING COMPLETE
JOINTS
CRENULATION CLEAVAGE
FOLDED QUARTZ VEINS
SLATY CLEAVAGE

Figure 71. Structural model, Dome Mountain gold camp.

ACKNOWLEDGMENTS

The author would like to thank Noranda Exploration Company, Limited for permission to work on their Dome Mountain properties. Discussions with Del Myers of Noranda were most helpful and his assistance is most gratefully acknowledged. The author was ably assisted in the field by Gary White, district geologist in Smithers, and Kurt Foellmer, a summer contract employee.

REFERENCES

Gaul, A. J. (1922): Report on Dome Mountain Claims, Telkwa, B.C., *B.C. Ministry of Energy, Mines & Pet. Res.*, Open File Rept., 9 pp.

L'Orsa, A. (1982): Preliminary Geological Report, Boo Mineral Claims, *B.C. Ministry of Energy, Mines & Pet. Res.*, Assessment Report, 10501, 7 pp.

Minister of Mines, B.C.: Annual Reports, 1915, 1916, 1918, 1922, 1923, 1924, 1934, 1938, 1940, 1951.

Tipper, H. W. and Richards, T. A. (1976): Jurassic Stratigraphy and History of North-Central British Columbia, *Geol. Surv., Canada*, Bull. 270, 73 pp.

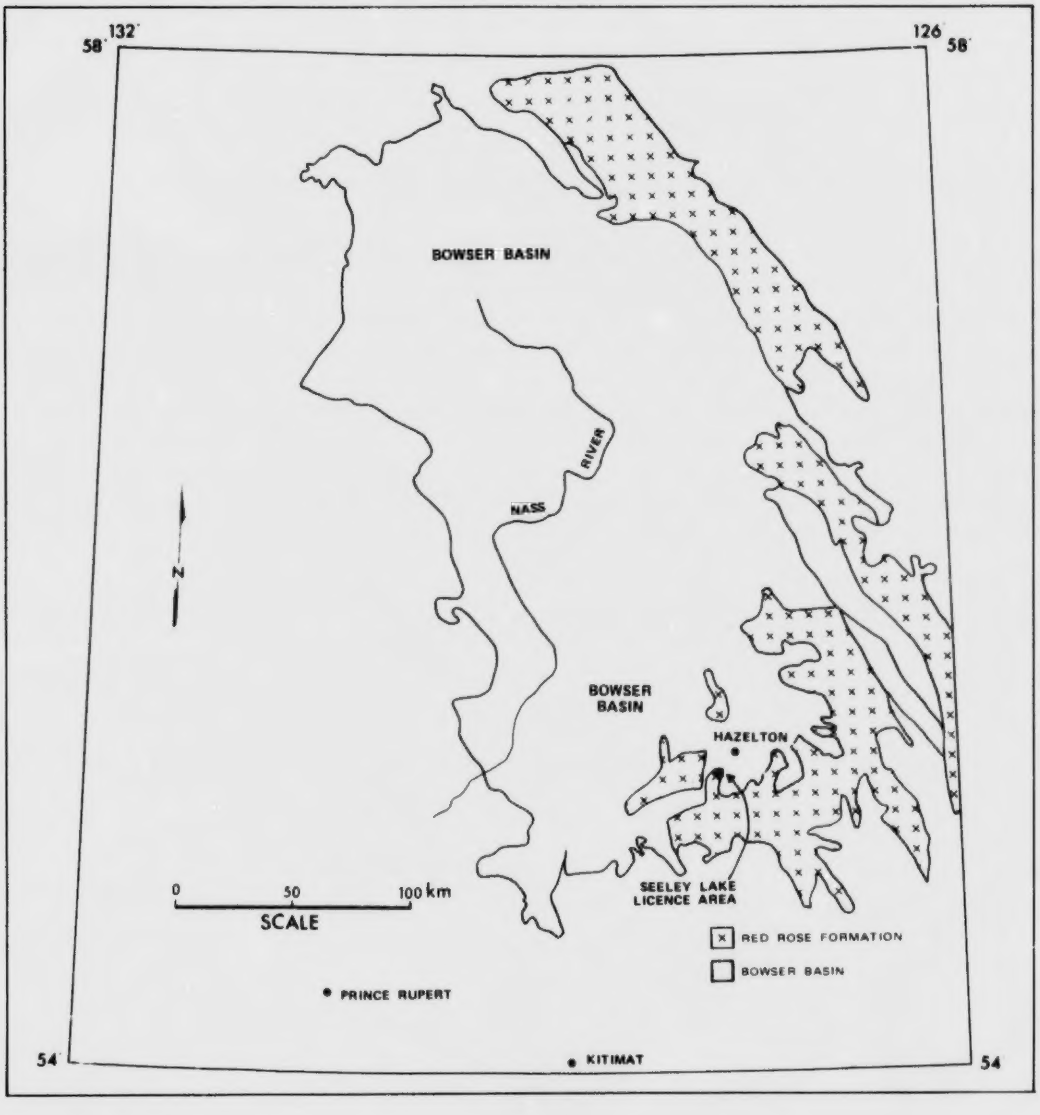

58°
132°
126°
58°
BOWSER BASIN
NASS
RIVER
N
BOWSER BASIN
HAZELTON
SEELEY LAKE LICENCE AREA
0
50
100 km
SCALE
☒ RED ROSE FORMATION
☐ BOWSER BASIN
PRINCE RUPERT
KITIMAT
54°
54

Figure 72. Geological setting of the Seeley Lake area in the Bowser Basin.

THE SEELEY LAKE COAL PROSPECT
(93M/4E)

By G. V. White

INTRODUCTION

The Seeley Lake coal licences, held by D. Groot Logging Ltd. of Smithers, are located approximately 5 kilometres southwest of South Hazelton (Fig. 72). The seven coal licences cover 542 hectares and lie between the Skeena River and the Yellowhead Highway. Access to the property is by gravel road from Seeley Lake Park; much of the licence area has been logged and/or cleared for agricultural purposes.

Coal exposures on the property are poor; it was the mineral exploration arm of D. Groot Logging Ltd. which encountered coal in 1981 in Lower Cretaceous sediments of the Red Rose Formation. The company was drilling around a granitic intrusion on a mineral prospect when they encountered coal in one of their diamond-drill holes. The coal was analysed and found to be of anthracite to meta-anthracite rank. The company then completed step-out holes to determine the extent of the intersected coal seam.

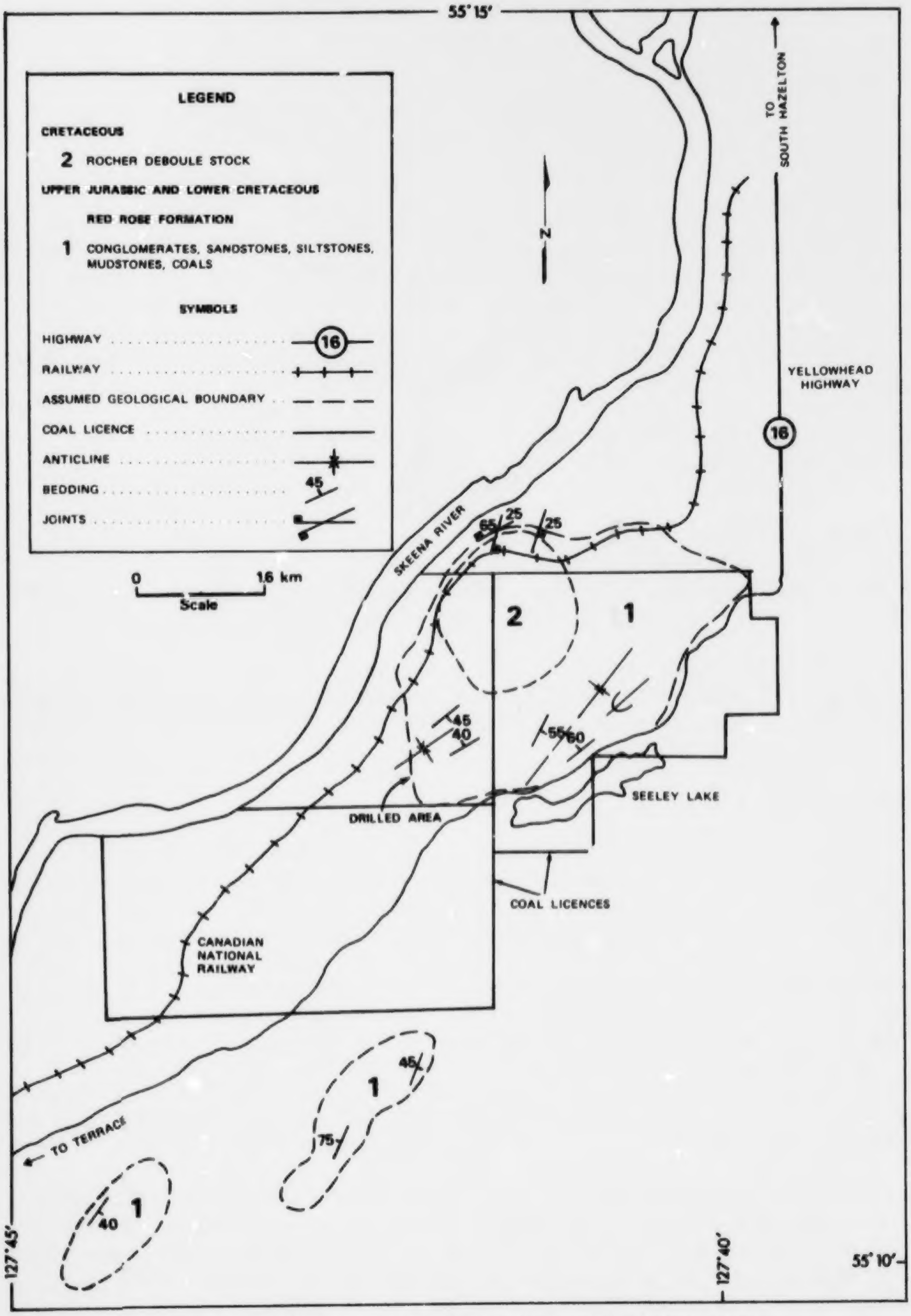
Since the initial coal discovery in 1981, 20 diamond-drill holes have been completed, three in 1982, and 17 in 1983. Core from 10 of these holes were examined during the summer of 1984.

STRATIGRAPHY

The sedimentary sequence within the Seeley Lake licence area (Fig. 73) belongs to the lowermost unit of the Upper Jurassic to Lower Cretaceous Red Rose Formation (Sutherland Brown, 1960). The sequence consists of interbedded conglomerates, sandstones, siltstones, mudstones, and coals.

The sandstones are feldspathic and range from fine to coarse in grain size. In places they are carbonaceous and contain occasional plant fragments. The fine-grained sandstones are medium to dark grey in colour and range in thickness from 0.2 to 20 metres. The medium-grained sandstones are light to medium grey in colour; units range in thickness from 0.2 to 20 metres. The coarse-grained sandstones are light grey in colour and intervals of coarse sands range from 0.2 to 2 metres.

The conglomerates range from 0.2 to 17 metres in thickness. The matrix is variably fine to coarse sandstone. The units are poorly to well sorted reflecting a fluctuating energy level during sediment deposition. The clasts consist of subrounded to angular black to grey chert and volcanic rock and range up to 5 centimetres in size.



55°15'
LEGEND
CRETACEOUS
2 ROCHER DEBOULE STOCK
UPPER JURASSIC AND LOWER CRETACEOUS
RED ROSE FORMATION
1 CONGLOMERATES, SANDSTONES, SILTSTONES, MUDSTONES, COALS
SYMBOLS
HIGHWAY
16
RAILWAY
ASSUMED GEOLOGICAL BOUNDARY
COAL LICENCE
ANTICLINE
BEDDING
45
JOINTS
0
1.6 km
Scale
N
TO SOUTH HAZELTON
YELLOWHEAD HIGHWAY
16
SKEENA RIVER
65
25
25
2
1
45
40
55
60
SEELEY LAKE
DRILLED AREA
COAL LICENCES
CANADIAN NATIONAL RAILWAY
1
45
75
TO TERRACE
1
40
127°45'
127°40'
55°10'

Figure 73. Geology of the Seeley Lake coal licence area.

The mudstones and siltstones are generally black, although locally dark grey; they range in thickness from 0.2 to 36 metres.

The coals are anthracite to meta-anthracite in rank. Individual coal seams range up to 1.5 metres in thickness and aggregate intervals, which include mudstone partings, can be up to 12 metres. The coals are generally associated with mudstones, siltstones, and fine-grained sandstones. Up to six coal seams have been identified in the drilled sections.

One of the Rocher Deboule stocks of Late Cretaceous to Tertiary age thermally metamorphosed the siltstones and mudstones (Sutherland Brown, 1960) and produced the higher rank anthracite to meta-anthracite of the Seeley Lake sequence (Koo, 1984).

DEPOSITIONAL ENVIRONMENT

Koo (1984) suggested that active pedimentation across the Skeena Arch and west of the Omineca Crystalline Belt prevailed during the development of coal in the Seeley Lake area.

Pronounced fining upward sequences occur with conglomerates and/or coarse sandstones marking the start of each cycle. Some of the sandstones are crossbedded. These sequences suggest that the coarser sediments were laid down by streams meandering across flood plains. The coals are probably limnic type and formed inland in freshwater swamps and channels. For this reason coal seams within the Red Rose Formation are likely to vary in thickness and in lateral extent.

CONCLUSIONS

The Seeley Lake coal licences are underlain by the Red Rose Formation of the Early Cretaceous Skeena Group. The sedimentary sequence within the study area consists of interbedded sandstones, mudstones, siltstones, conglomerates, and coals. The coals are of anthracite to meta-anthracite rank as a result of thermal metamorphism by a granitic intrusive body in close proximity to the licence area. The coal deposit represents a limnic-type deposit which is reflected in the fining upward cycles of the Seeley Lake sequence.

Potential for further coal seams exists within the Red Rose Formation sediments, both stratigraphically above and below the studied section. The lateral extent of the coal seams may be limited because of the nature of deposition; however, locally individual seams could be thick.

ACKNOWLEDGMENTS

I would like to thank D. Groot Exploration Ltd. and B. Plecash for their cooperation, J. Koo for constructive criticism of the manuscript, and K. Foellmer for his able assistance in the field.

REFERENCES

Koo, J. (1984): The Telkwa, Red Rose, and Klappan Coal Measures in Northwestern British Columbia, *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1983, Paper 1984-1, pp. 81-91.

Sutherland Brown, A. (1960): Geology of the Rocher Deboule Range, *B.C. Ministry of Energy, Mines & Pet. Res.*, Bull. 43, 78 pp.

PINK CADILLAC PROSPECT

(93M/5E)

By T. G. Schroeter

INTRODUCTION

The Pink Cadillac property is located 5 kilometres east of Hazelton, on the north side of the Bulkley River at approximate latitude 55 degrees 16 minutes north and longitude 127 degrees 32 minutes west. The property is owned by Willis Korff, a local prospector. Access to the property is by road along the north side of the Bulkley River to the base of Four Mile Mountain, approximately 8.7 kilometres from Hazelton. The southern portion of the property, on the south side of the Bulkley River, may be reached by a short walk from the Ross Lake Provincial Park site.

The showings occur near water level in a canyon along the Bulkley River (Fig. 74).

PROPERTY GEOLOGY

The property is underlain by sandstone, siltstone, shale, and associated hornfels and bleached tuffaceous rocks which belong to the Bowser Lake Group of Late Jurassic to Early Cretaceous age. The rocks strike 060 degrees and dip 60 degrees to the southeast. On the north side of the Bulkley River, several dykes of granodiorite that intrude the sedimentary rocks are probably related to the granodiorite stock of Eocene age which underlies Four Mile Mountain.

STRUCTURE

A shear zone which is up to 75 metres wide has been traced across the property; it strikes 055 degrees and dips steeply to the northwest (Fig. 74). The structure can be traced for approximately 800 metres along strike and is covered at both ends by talus and overburden. Locally, especially on the north side of the river, highly polished slickensides characterize the fault zone; mineralization occurs in quartz vein(s) within it.

ALTERATION

The host rocks are bleached and pyritized adjacent to the quartz veins in the shear zone. Hornfelsing occurred adjacent to dykes of granodiorite. Silicification brecciation in the fault zone is the key alteration feature associated with mineralization. Clay minerals are not prominent.

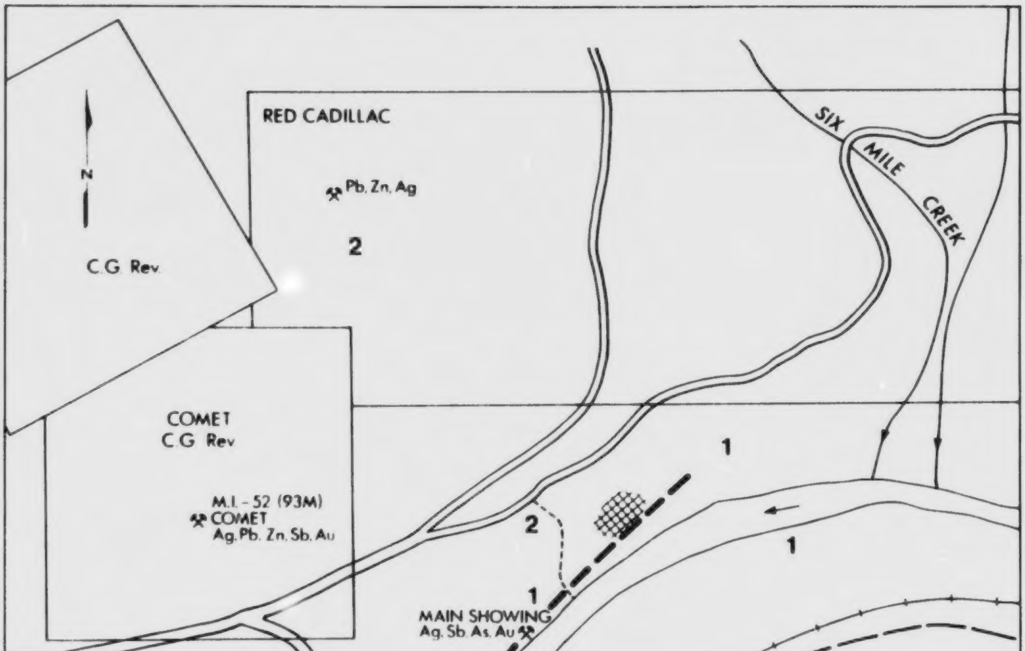

N
RED CADILLAC
Pb. Zn. Ag
2
C.G. Rev.
SIX MILE CREEK
COMET
C.G. Rev.
M.I. - 52 (93M)
COMET
Ag. Pb. Zn. Sb. Au
1
2
1
1
MAIN SHOWING
Ag. Sb. As. Au
To New Hazelton approx. 8 km
GRAVEL PIT
1
Mo
2
3
1
2
1
ROSS LAKE
PROVINCIAL PARK
BULKLEY RIVER
CANADIAN NATIONAL
PINK CADILLAC
0
300
SCALE-METRES
To New Hazelton 3 km
LEGEND
TERTIARY
EOCENE
2 BABINE INTRUSIONS GRANODIORITE
JURASSIC AND CRETACEOUS
UPPER JURASSIC AND LOWER CRETACEOUS
1 BOWSER LAKE GROUP 'UPPER BOWSER LAKE SUBDIVISION' SANDSTONE, SILTSTONE, SHALE
SYMBOLS
SHEAR ZONE, APPROXIMATE
GEOLOGICAL CONTACT, APPROXIMATE
ADIT
MINERAL INVENTORY NUMBER M.I.-52
MINERAL OCCURRENCE
FOOT TRAIL
GOSSAN ALTERATION
CABIN
Ag SILVER
Pb LEAD
Zn ZINC
Sb ANTIMONY
Au GOLD
Mo MOLYBDENUM
As ARSENIC

Figure 74. Geological sketch map of the Pink Cadillac prospect.

MINERALIZATION

The Main vein can be traced for 125 metres along strike with an average width of 1.5 metres; however, where the vein splits into small quartz veins the zone is up to 10 metres wide. Pyrite, berthierite, miargyrite, marcasite, jamesonite, arsenopyrite, and probably other as yet unidentified ruby silver minerals occur in a quartz breccia with minor amounts of clay minerals (including some sericite) and siderite. The sulphosalt minerals and the miargyrite have been identified by the Mines Branch, Geological Survey of Canada in Ottawa and at the laboratory of the British Columbia Ministry of Energy, Mines and Petroleum Resources in Victoria. Miargyrite, $AgSbS_2$, is a very rare mineral and Mr. Korff's discovery of such is the first documented occurrence in Canada and the first in the world since 1919. The quartz gangue is very fine grained and locally rebrecciated with drusy cavities. Assays of high-grade grab samples taken by the writer returned values as high as 11 900 ppm silver (350 ounces silver per ton). Minor amounts of gold appear to be associated with the arsenopyrite.

Elsewhere on the property, minor amounts of molybdenite, as well as minor disseminated arsenopyrite, occur in association with granodiorite dykes.

REFERENCES

B.C. Ministry of Energy, Mines & Pet. Res., Assessment Report 11900.

Geol. Surv., Canada, Geology of Hazelton Map Area, British Columbia, Open File 720.

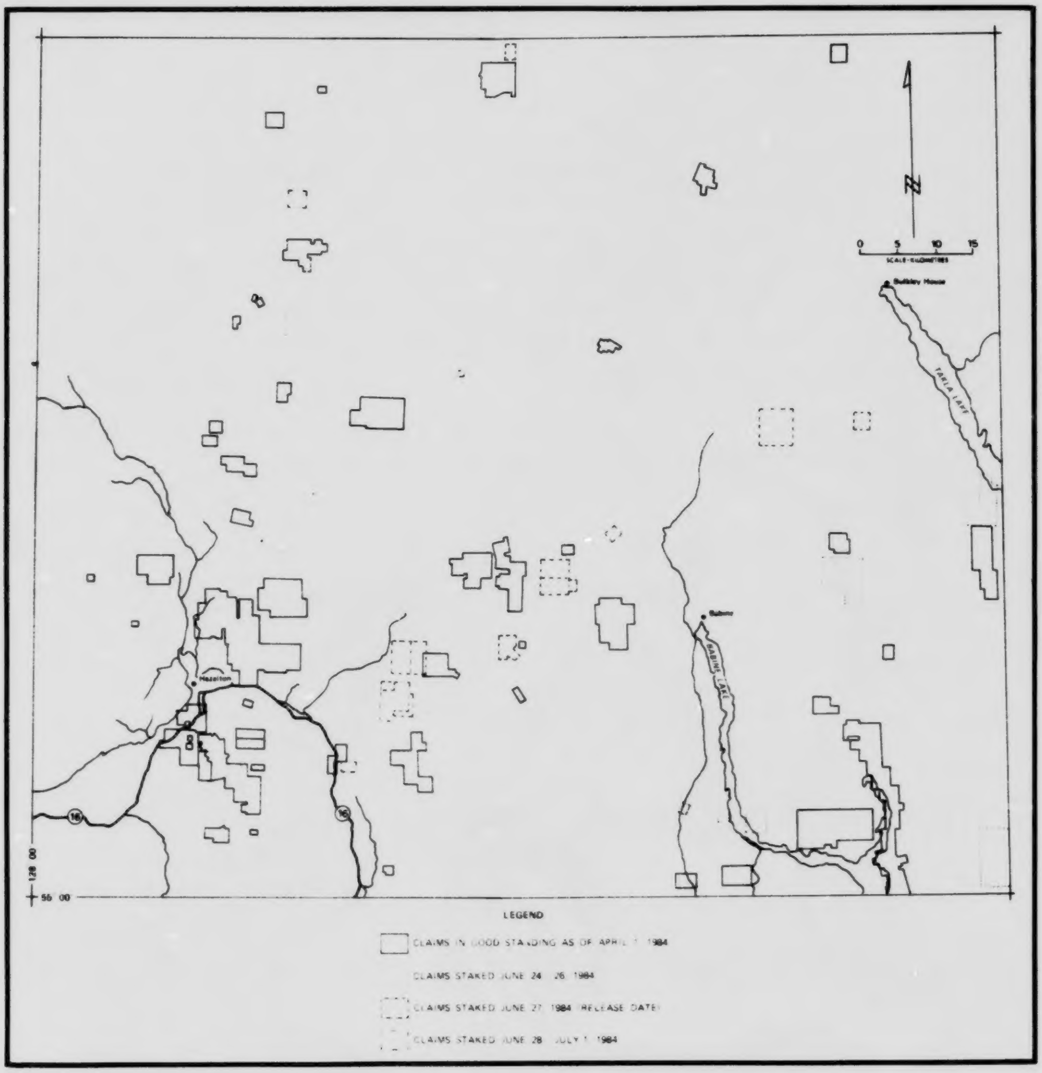

0 5 10 15
SCALE-KILOMETRES
Bulkley House
TAKLA LAKE
Babine
BABINE LAKE
Hazelton
16
16
128 00
56 00
LEGEND
CLAIMS IN GOOD STANDING AS OF APRIL 1 1984
CLAIMS STAKED JUNE 24 26 1984
CLAIMS STAKED JUNE 27 1984 (RELEASE DATE)
CLAIMS STAKED JUNE 28 JULY 1 1984

Figure 75. New staking (June 24 to July 1) and active claim status (April 1, 1984), Hazelton area, 93M.

BRITISH COLUMBIA REGIONAL GEOCHEMICAL SURVEY (RGS) DATA RELEASE
SUMMARY OF RESULTS
(93M, 93N)

By T. G. Schroeter and G. V. White

INTRODUCTION

Data from the joint Federal/Provincial reconnaissance Regional Geochemical Surveys conducted during the summer of 1983 were released simultaneously at 08:30 PDT on June 27, 1984 in Smithers, Fort St. James, Vancouver, and Victoria.

NTS Survey Area	Province of B.C. Open File	Geological Survey of Canada Open File
93M	BC-RGS-10-1983	1000
93N	BC-RGS-11-1983	1001

These surveys cover approximately 28 000 square kilometres at an average sample density of one sample per 13 square kilometres. Stream sediment samples were analysed for copper, lead, zinc, nickel, cobalt, silver, arsenic, antimony, molybdenum, iron, hydrogen, uranium, tungsten, and manganese. Stream waters were analysed for uranium, fluorine, and pH. Each Open File consists of 17 geochemical maps, sample location map, and text of field observations, analytical and statistical data. Cost is $55.00 for each map sheet package; they are available from: Publications Distribution, 552 Michigan Street (basement), Victoria, British Columbia, V8V 1X4.

RESULTS

Number of map sheet packages sold:

	93M	93N	No. of Representatives
Smithers	22	14	20
Fort St. James*	1	24	10
Vancouver*	28	32	35
Victoria*	4	4	6
TOTAL	55	74	71

*Approximate

The weather during the day of the release was terrible - overcast and cold with rain and snow at higher elevations.

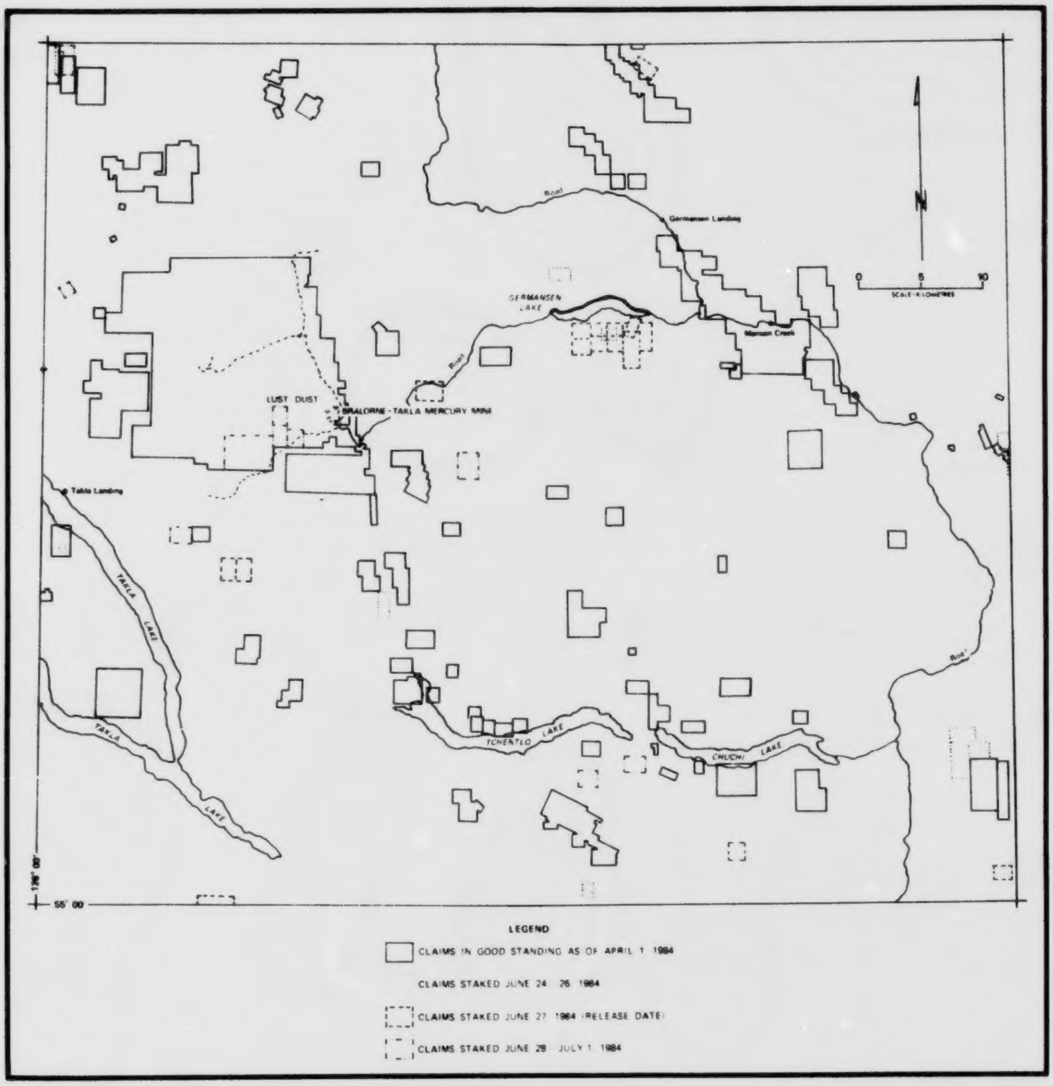

Road
Germansen Landing
N
0
5
10
SCALE - KILOMETRES
GERMANSEN LAKE
Manson Creek
River
LUST DUST
BRALORNE - TAKLA MERCURY MINE
Takla Landing
TAKLA LAKE
TAKLA LAKE
TCHENTLO LAKE
CHUCHI LAKE
Road
126° 00'
55° 00'
LEGEND
CLAIMS IN GOOD STANDING AS OF APRIL 1 1984
CLAIMS STAKED JUNE 24 26 1984
CLAIMS STAKED JUNE 27 1984 (RELEASE DATE)
CLAIMS STAKED JUNE 28 JULY 1 1984

Figure 76. New staking (June 24 to July 1) and active claim status (April 1, 1984), Manson River area, 93N.

In anticipation of the RGS release scheduled for June 27, 1984, we listed and plotted all mineral claims in good standing as of April 1, 1984 within map sheets 93M (Hazelton) and 93N (Manson Creek) on British Columbia Government Mineral Maps and on topographic maps at a scale of 1:250 000 (Figs. 75 and 76).

MAP SHEET 93M (Hazelton)

(1) Immediately prior to the RGS release between June 20 and 26, 1984, 368 units were staked.

(2) On the actual day of the release, June 27, 1984, 402 units and 32 two-post claims were staked.

(3) Immediately following the release between June 28 and July 1, 1984, 64 units and three two-post claims were staked.

Therefore a total of 834 units and 35 two-post claims were staked in map sheet 93M as a direct result of the June 27, 1984 RGS release.

MAP SHEET 93N (Manson Creek)

(1) Immediately prior to the RGS release between June 20 and 26, 1984, 173 units and six two-post claims were staked.

(2) On the actual day of the release, June 27, 1984, 266 units and 40 two-post claims were staked.

(3) Immediately following the release between June 28 and July 1, 1984, 380 units and nine two-post claims were staked.

Therefore a total of 819 units and 55 two-post claims were staked in map sheet 93N as a direct result of the June 27, 1984 RGS release.

SUMMARY

(1) A total of 1 653 units and 90 two-post claims were staked as a direct result of the RGS release held June 27, 1984 in map sheets 93M and 93N.

(2) In map sheet 93M this increased by approximately 35 per cent the total number of active claims in the area.

(3) In map sheet 93N there was an approximate increase of 16.3 per cent the total number of active claims in the area.

COMMENTS

(1) The turnout on the day of the release was surprisingly low.

(2) Few major companies participated directly, whereas several junior companies and prospectors were actively involved.

(3) Anomalies of pathfinder elements for precious metals and massive sulphide deposits appear to have been the main targets.

(4) Slightly more interest was shown in NTS 93M (Hazelton) than in 93N (Manson Creek).

(5) Comparatively, the number of units and two-post claims staked as a direct result of this year's RGS release was surprisingly good, considering the low turnout at the release.

(6) The weather on the day of the release was terrible and the very late snow pack also may have hampered work.

(7) On-site investigations of new claims continued during the summer of 1984 on both map sheets. It is premature to assess the significance of any new discoveries.

GEOLOGY OF THE WEST CARBON CREEK AREA

(930/15)

By A. Legun

INTRODUCTION

The West Carbon Creek area is located 40 kilometres west of the W.A.C. Bennett Dam in northeastern British Columbia (Fig. 77). Fieldwork in 1984 was directed toward compilation of the geology of a major syncline which contains up to 1 200 metres of coal measures. Previous work includes that of Matthews (1947), Stott and Gibson (1980), Legun (1983), Stott (1983), and personnel of Utah Mines Ltd. and Gulf Canada Resources Inc. (1980-1983 assessment reports). The area includes the West Carbon Creek licences of Utah Mines and the former Whiterabbit licence block of Gulf Canada.

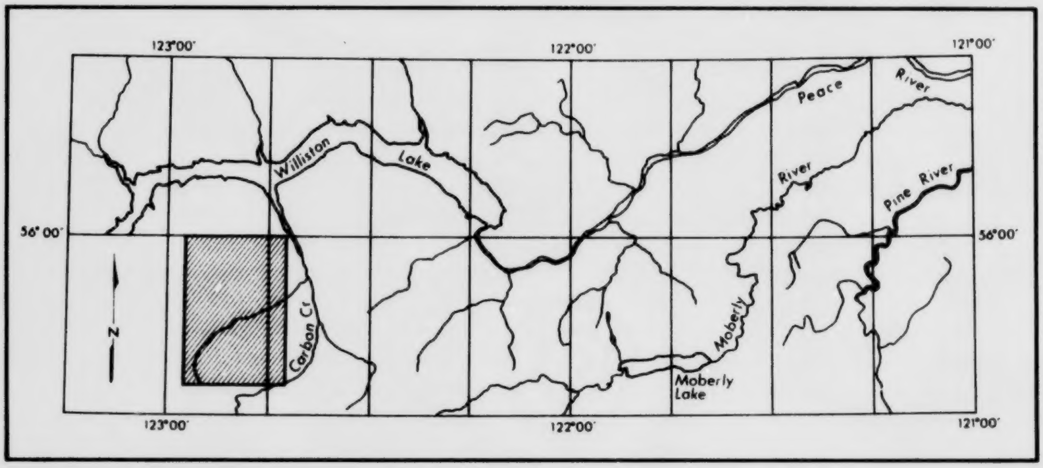
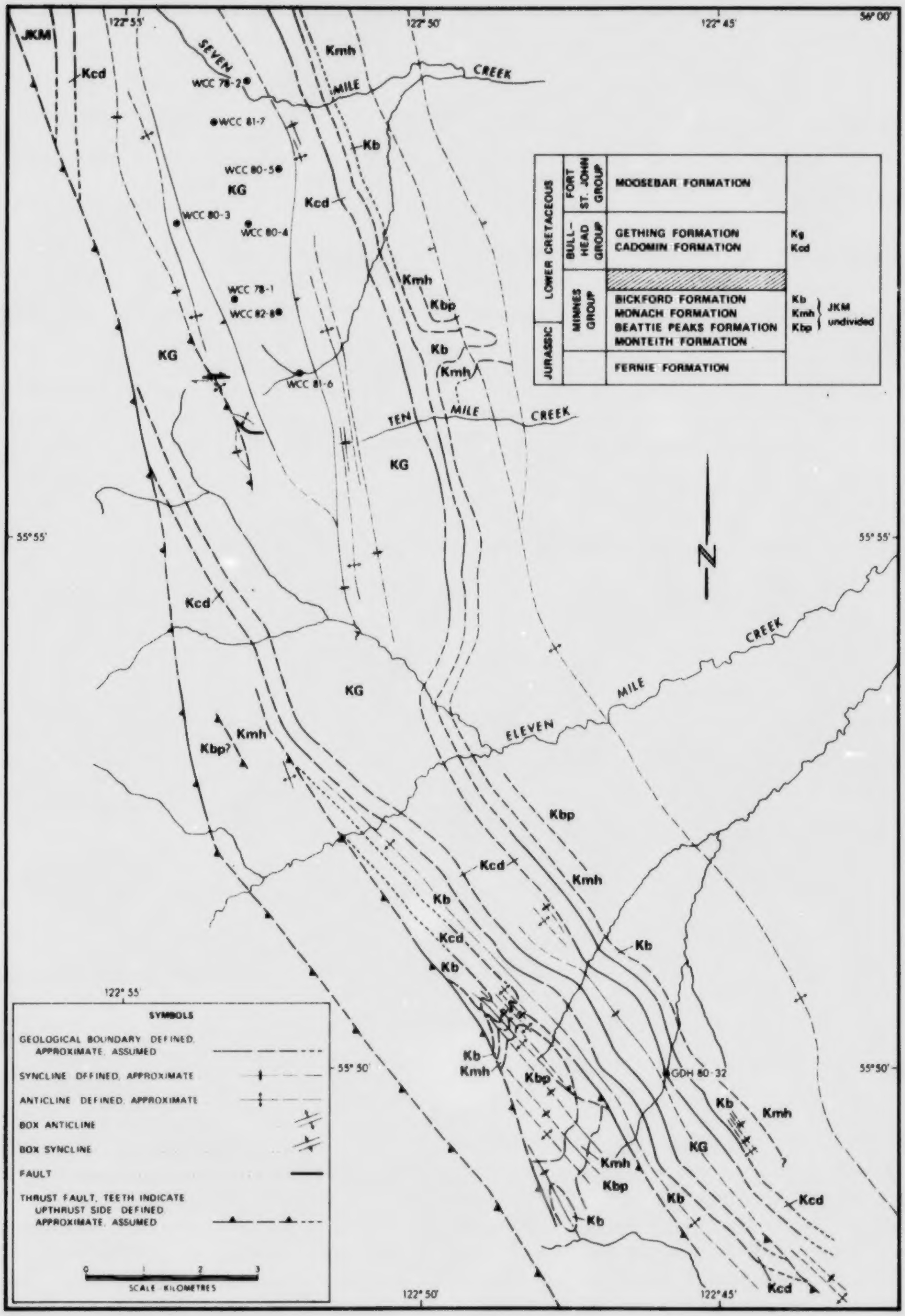


Figure 77. Location of the West Carbon Creek map-area.

Previous work has not resolved either the geology or the stratigraphy of the area. Maps of Utah Mines, Gulf Canada, and the Geological Survey of Canada conflict in the position, thickness, and boundaries of the Cadomin, Bickford, and Monach Formations. For a time the coal measures themselves were assigned to the Bickford Formation (Stott and Gibson, 1980) but have since been reassigned to the Gething Formation. In the north Utah Mines reported more than 1 000 metres of coal measures, while to the south Gulf Canada considered only a few hundred metres to be



122° 55'
122° 50'
122° 45'
56° 00'
55° 55'
55° 50'
JKM
Kcd
SEVEN MILE CREEK
Kmh
WCC 78-2
WCC 81-7
Kb
WCC 80-5
KG
Kcd
WCC 80-3
WCC 80-4
WCC 78-1
WCC 82-8
Kmh
Kbp
Kb
(Kmh)
KG
WCC 81-6
TEN MILE CREEK
KG
Kcd
KG
ELEVEN MILE CREEK
Kmh
Kbp?
Kbp
Kcd
Kmh
Kb
Kcd
Kb
Kb
Kb
Kmh
Kbp
GDH 80-32
Kb
Kmh
KG
?
Kmh
Kbp
Kb
Kb
Kcd
Kcd
LOWER CRETACEOUS
JURASSIC
FORT ST. JOHN GROUP
BULL-HEAD GROUP
MINNES GROUP
MOOSEBAR FORMATION
GETHING FORMATION
CADOMIN FORMATION
BICKFORD FORMATION
MONACH FORMATION
BEATTIE PEAKS FORMATION
MONTEITH FORMATION
FERNIE FORMATION
Kg
Kcd
Kb
Kmh
Kbp
JKM undivided
SYMBOLS
GEOLOGICAL BOUNDARY DEFINED, APPROXIMATE, ASSUMED
SYNCLINE DEFINED, APPROXIMATE
ANTICLINE DEFINED, APPROXIMATE
BOX ANTICLINE
BOX SYNCLINE
FAULT
THRUST FAULT, TEETH INDICATE UPTHRUST SIDE DEFINED, APPROXIMATE, ASSUMED
0
1
2
3
SCALE KILOMETRES

Figure 78. West Carbon Creek map-area (930/15). Geology of a major coal-bearing syncline is shown.

present. Stott (1983) shows Moosebar and Gates Formations to be present in the core of the syncline; this interpretation is doubted both by other Geological Survey of Canada personnel and by coal company personnel.

The writer spent 16 field days tracing and mapping geologic units in the vicinity of the syncline. Field data was integrated with air photograph examination and relevant data from previous maps. Essentials of the geology are shown on Figure 78. The mapping enabled reinterpretation of the structure and the stratigraphy.

STRUCTURE AND STRATIGRAPHY

The trace of the Cadomin Formation delineates the major syncline. The syncline is flat bottomed and box-like on Utah Mines' licences but closes and becomes very tight southward on Gulf's former licences. Tight folding with minor thrust faulting marks each steep limb of the fold. The structure may plunge southeast because the coal measures do not extend northward to Williston Lake. Similar reasoning suggests a northwest plunge in the south, therefore a doubly plunging syncline. The syncline is faulted at its south end, according to Gulf Canada's 1982 mapping.

The area of the 'box' structure is structurally delineated on Figure 78. Strata are flat lying within an elongate diamond-shaped area, whose north end is outside the map-area. High ground in the south half of the 'diamond' contains the uppermost preserved beds of the Gething Formation. An arenite marker unit at the base of a prominent hill has been correlated to the north and east. To the north it corresponds to the very top of diamond-drill hole 82-8 (Utah Mines). Beds above the marker, which comprise the remaining 120-metre height of the hill, have not been intersected in any Utah Mines' drill holes and are additional to the section measured by Stott on the west slope of Mount Rochfort. A total thickness of 1 100±100 metres for the Gething Formation is calculated by the writer. Stott assigned strata of the hill to the Gates Formation. Stott's Moosebar Formation is an anomalously thin 60-metre mudstone interval below the marker. However, field examination indicates that the whole interval is better assigned to the coal measures of the Gething Formation.

BULLHEAD GROUP

GETHING FORMATION

The Gething Formation is a coal measure sequence consisting of interbedded thin coals that are usually less than 1 metre thick, carbonaceous shales, mudstone, siltstone, arenite, and lesser calcareous equivalents. In the West Carbon Creek area the sequence appears to be sandier than it is in the east (for example, Peace River Canyon section). It is also distinguished by the presence of channel conglomerates 5 to 10 metres thick and 50 to 100 metres in apparent width. In the flat-lying beds of the 'box' structure, channel deposits that are within coal measures correlate laterally with extensive sheet-like, crossbedded units of arenite, pebbly arenite, and conglomerate. One of these 'sheets' is the important local marker unit discussed previously that is exposed beside the site of diamond-drill hole 82-8 (Fig. 78). Other channel bodies correlate laterally with interbedded coal measure lithologies; these may be fluvial overbank deposits.

Gulf Canada trenched one 3-metre coal seam at the south end of the syncline in the Gething Formation. Their single drill hole was spudded in the Cadomin Formation; therefore it left the interval of Gething Formation untested. In the north, Utah Mines drilled eight holes in the Gething Formation but did not intersect an economically interesting thickness of coal. Worth pursuing is a 1.5-metre seam, 10 metres below the top of diamond-drill hole 82-8. It should also be present in an undrilled area to the south, in the vicinity of the prominent hill described previously.

CADOMIN FORMATION

The Cadomin Formation is characterized by thick, up to 10-metre, sandstone to pebbly sandstone units with thinner recessive intervals. Consequently the formation tends to form 'ribbed' ridges that can be traced on air photographs. The proportion of resistant units to recessive intervals varies laterally and vertically within the formation. Locally thick carbonaceous recessive intervals develop laterally so that basal Gething Formation coal measures grade into upper Cadomin Formation pebbly sandstones or vice versa.

In the West Carbon Creek area the Cadomin Formation varies from 200 to 275 metres in thickness, comparable to thicknesses well to the east in the Butler Ridge area (Legun, 1984). No westward thickening is indicated. The proportion of conglomerate is less than in the east, which suggests that the source is not from the west. Perhaps deposits of the Cadomin Formation are related to the outlet of the Spirit River channel drainage system to the east (McLean, 1977). Paleocurrent data is required to resolve this question.

Utah Mines' designation of a thin (40 to 60-metre) unit as the Cadomin Formation is incorrect. It and the coal measures below are actually in the Gething Formation; the Cadomin lies stratigraphically below.

MINNES GROUP

BICKFORD FORMATION

This formation consists of salt-and-pepper sandstones, massive and low angle crossbedded (flaggy) arenite, quartz arenite, carbonaceous shale, thin coals, and local thin beds of grit. The contact with the Cadomin Formation is gradational to lithologically distinct. The presence of flaggy beds, salt-and-pepper sandstones, and local quartz arenites, together with the absence of thick pebbly units, distinguishes the Bickford from the Cadomin Formation. On air photographs the Bickford tends to be a recessive band between the more resistant units of the Cadomin and Monach Formations; exposure is fair to poor.

This formation is distinct to the south, west of Mount Monach, but loses lithological identity to the north. There it becomes increasingly dominated by flaggy arenites and indistinguishable from the Monach Formation, except for the presence of carbonaceous intervals. The Bickford Formation is about 150 metres thick and appears to thicken slightly to the south in the Mount Monach area. It must thicken considerably between there and Mount Bickford where Stott (1981) measured 348 metres of section.

MONACH FORMATION

The Monach Formation is typified by units of flaggy, planar to shallow crossbedded arenites; massive arenite; and minor amounts of quartz arenite. Coquinas of *Buchia* are present toward the base of the formation in exposures east of the principal syncline. The Monach forms the top of a coarsening upward sequence that begins in the shales of the Beattie Peaks Formation. The contact between the two formations is arbitrarily placed where shaly interbeds of the Beattie Peaks disappear; thickness varies from 100 to 200 metres. Sedimentary structures indicate a shallowing upward marine sequence ending with beach and shoreface deposits.

CONCLUSIONS

The Cadomin Formation in West Carbon Creek area is mappable and can be used to delineate the border of the coal-bearing syncline, as well as to separate the stratigraphy above (Gething Formation) from that below (Minnes Group).

The maximum thickness of Gething Formation is reached at the south end of the flat-bottomed portion of the syncline on a flat-topped hill with elevation 1 819 metres. Total thickness is 1 100±100 metres.

No Gates or Moosebar Formation rocks are present in the core of the syncline.

Fluvial channel deposits in the Gething Formation pass laterally into sheet-like bodies of pebbly sandstone which locally form marker units.

In the south the syncline becomes tight and has vertical dips in the axial zone. Only the lower part of the Gething Formation is present there.

The Bickford Formation is thinner than on previous maps and its trace on the map differs considerably from interpretations by Stott and Utah Mines personnel. The Bickford Formation has poor coal development and loses distinctive lithological character northward, where it is increasingly dominated by flaggy arenites that are typical of the Monach Formation; this is interpreted to reflect an increasing marine influence northward.

REFERENCES

Cowley, P. S. (1981-1983): Report of Exploration Activities on the West Carbon Creek Property, *Utah Mines Ltd.*, unpub. repts.

Gulf Canada Resources Inc., Goodrich Coal Project Geological Repts. 1981-1983.

Legun, A. (1983): Stratigraphy and Sedimentology Notes on the Bullhead Mountain-Peace River Canyon, Carbon Creek Area, Northeastern British Columbia (930/15, 16; 94B/1, 2), *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1982, Paper 1983-1, pp. 93-98.

.... (1984): Butler Ridge Map-area (94B/1), *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1983, Paper 1984-1, pp. 123-130.

Matthews, W. H. (1947): Geology and Coal Resources of the Carbon Creek-Mount Bickford Map-area, *B.C. Ministry of Energy, Mines & Pet. Res.*, Bull. 24.

McLean, J. R. (1977): The Cadomin Formation: Stratigraphy, Sedimentology and Tectonic Implications, *Cdn. Pet. Geol.*, Bull., Vol. 25, No. 4, pp. 792-827.

Stott, D. F. (1981): Bickford and Gorman Creek, Two New Formations of the Jurassic-Cretaceous Minnes Group, Alberta and British Columbia, *in* Current Research, Part B, *Geol. Surv., Canada*, Paper 81-1B, pp. 1-9.

.... (1983): Mackenzie Map-area, British Columbia, *Geol. Surv., Canada*, Open File 925.

Stott, D. F. and Gibson, D. W. (1980): Minnes Coal, Northeastern British Columbia, *in* Current Research, Part C, *Geol. Surv., Canada*, Paper 80-1C, pp. 135-137.

NUMERICAL DEPOSITIONAL MODELLING - GETHING FORMATION ALONG THE PEACE RIVER

(93O, 94A, 94B)

By W. E. Kilby and H. P. Oppelt

INTRODUCTION

This study was initiated during the 1984 field season to examine the lower Moosebar and upper Gething Formations along the Peace River. Volcanic ash bands, tonsteins and bentonites, occur in the lower Moosebar Formation (Kilby, 1984b) and were recognized in the upper Gething Formation of this area during the 1984 field season; they provided excellent marker horizons on which to base regional correlations. A total of 1 280 metres of drill core was examined from 16 boreholes spanning an east-west distance of 100 kilometres (Fig. 79). This paper presents a preliminary correlation of these strata along the Peace River (Fig. 80) and a numerical analysis of the sedimentary sequences undertaken in an effort to generalize the sedimentary pattern of the area.

Many workers have contributed to the understanding of the stratigraphic position, lithologic character, and paleo-environments of deposition of formations along the Peace River. The number of authors is too great to list here but a few of the major contributors are D. F. Stott, J. E. Hughes, R. D. Gilchrist, and P.McL.D. Duff.

STRATIGRAPHY

The strata under study represents a regressive/transgressive cycle of the Albian Clearwater Sea. During the regressive phase non-marine fluviodeltaic sediments, including coal, were deposited. Flooding by the Clearwater Sea during the transgressive phase resulted in deposition of the marine Moosebar Formation. Sediments were predominately derived from the west, both from the Omineca Geanticline and the uplifting Rocky Mountain Fold and Thrust Belt. The development of the basin and its consequent infilling of clastic sediments seem to be related to a northeast-trending hingeline parallel to the ancient Peace River Arch (Stott, 1975).

The Gething Formation, in the interval examined in this study, contains a series of thin-bedded rocks, derived from overbank sediment, and coal. The sequence is occasionally broken by a thick fluvial sequence of sandstone and uncommon lag conglomerates. Three notable coal horizons are present in the interval examined:

(1) Superior seam, situated at the top of the formation directly in contact with the Bluesky unit or up to several metres below this contact;

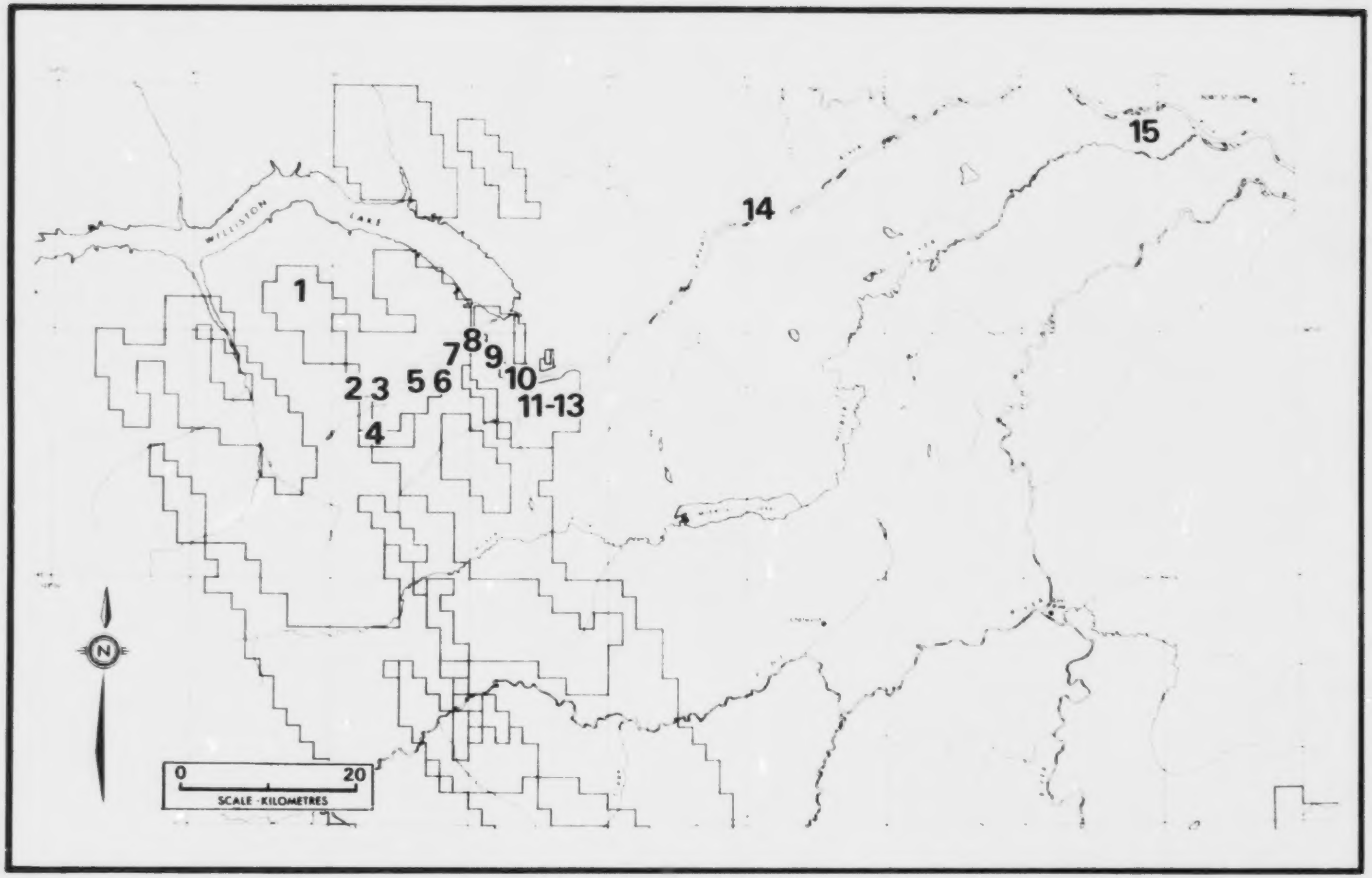

WILLISTON
LAKE
1
2
3
4
5
6
7
8
9
10
11-13
14
15
N
0
20
SCALE - KILOMETRES

Figure 79. Location map of diamond-drill holes examined along the Peace River.

(2) Trojan seam, located about 30 metres below the top of the formation. The Fisher Creek Tonstein zone has been located in this seam;

(3) Titan seam, located about 60 metres below the top of the formation. The No. 2 Tonstein is present in this seam along Moosebar Creek. Many minor seams occur between these three horizons and there is great difficulty in correlating the zones any great distance (Fig. 80). The seams, which are generally 1 to 2 metres thick, are of medium to high volatile bituminous rank.

Between the Gething and Moosebar Formations is an excellent marker horizon known as the Bluesky unit; it defines the top of the Gething Formation. This unit is considered to be equivalent to the Bluesky Formation in the Alberta subsurface. In the Peace River Canyon area, the Bluesky contains three principal units ranging from 1 to 25 metres in thickness; local accumulations are to 50 metres. The basal zone is a chaotic, sometimes glauconitic, chert pebble conglomerate with a mud or sand matrix and a scoured base. The scoured base may represent a hiatus in sedimentation. The conglomerate beds are massive with little sorting. Pebbles, which range from less than 1 to 5 centimetres in diameter, are generally subrounded to rounded. In places pebbles are absent and the basal zone is a coarse sand. The middle unit is a bioturbated and turbiditic silty, pyritic mudstone. Individual trubidites are usually less than 10 centimetres in thickness and the unit commonly exhibits a coarsening upward response on geophysical logs (Kilby, 1984a). The upper unit is a moderately bioturbated, glauconitic mudstone with thicknesses to several metres. Generally, glauconite occurs as scattered grains but sometimes dominates the zones as a coarse gritty sand. All three Bluesky units are believed to be marine; however their depositional history is still in question.

The Moosebar Formation overlies the Bluesky. It is a monotonous sequence of dark grey marine shales with occasional siderite bands or septarian concretions. The origin of the siderite bands is also uncertain but they are probably diagenetic. Numerous 1 to 15-centimetre-thick bentonite bands have recently been documented in the lower Moosebar Formation (Kilby, 1984b). Commonly, these bentonite bands are bioturbated; rare shell casts occur.

METHODOLOGY

The diamond-drill core was examined during a 15-day period in July, 1984 at the British Columbia Ministry of Energy, Mines and Petroleum Resources core storage facility in Charlie Lake, British Columbia. A total of 1 280 metres of core from 16 drill holes were described. Lithologies were grouped into one of 12 possible lithologic categories (Fig. 81). A total of 1 022 discrete rock units were measured. The lithologic categories are described in detail in a following section. Information was entered into a computer data base system using the CAL DATA LTD. Geological Analysis Package and a Kaypro II 64K micro-computer. Computer

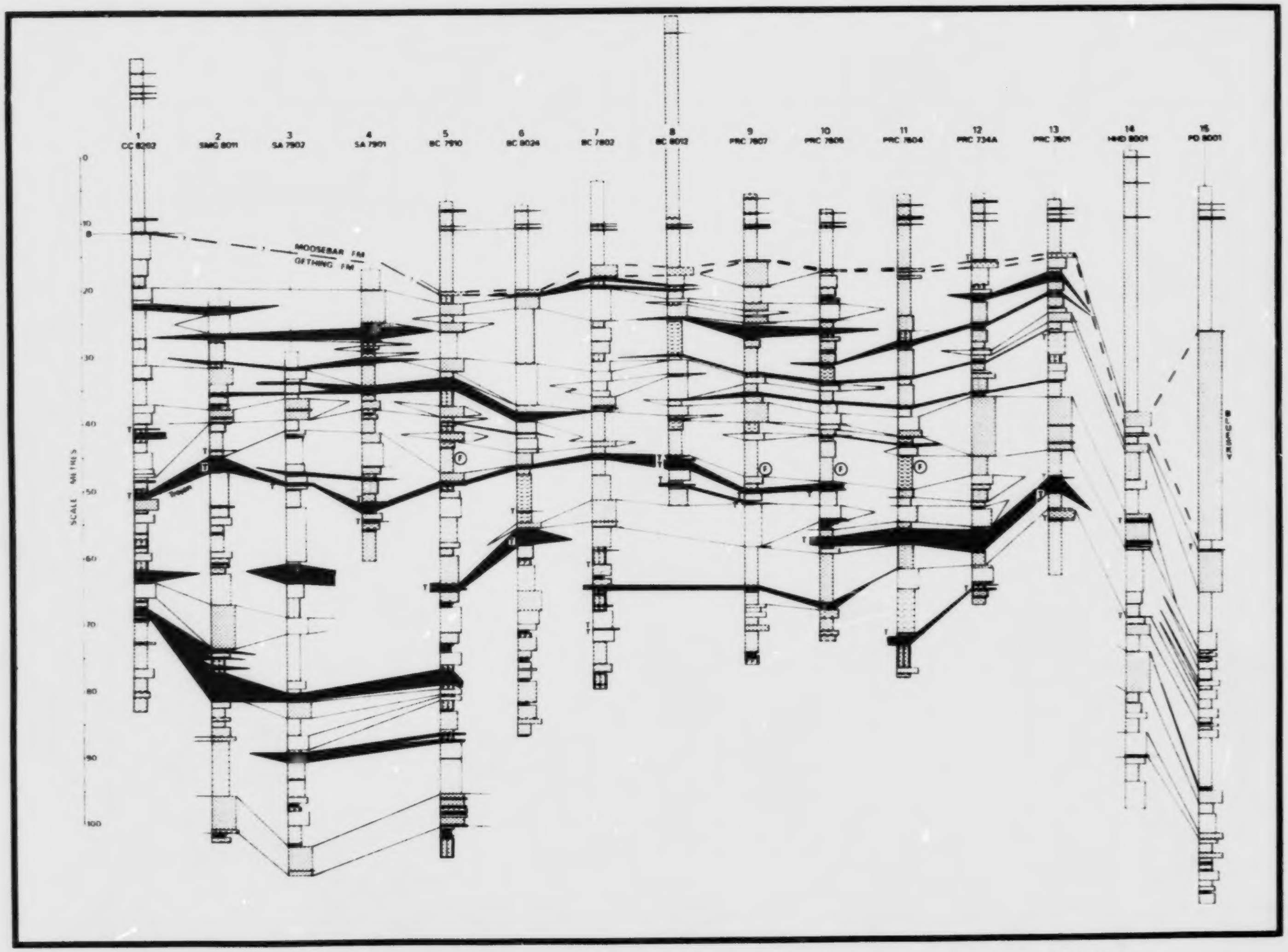

1
CC 8202
2
SMC 8011
3
SA 7902
4
SA 7901
5
BC 7910
6
BC 8024
7
BC 7802
8
BC 8012
9
PRC 7807
10
PRC 7805
11
PRC 7804
12
PRC 734A
13
PRC 7801
14
HHD 8001
15
PD 8001
MOOSEBAR FM
GETHING FM
SCALE METRES
0
10
20
30
40
50
60
70
80
90
100
T
F

Figure 80. Schematic diagram of lithologies measured from the lower Moosebar and upper Gething Formations along the Peace River.

■	COAL
▥	MUDSTONE:CARBONACEOUS
▤	MUDSTONE:NONCARBONACEOUS
▤	MUDSTONE WITH SANDSTONE STREAKS
▤	MUDSTONE WITH SANDSTONE LENSES
▤	SANDSTONE,MUDSTONE,SILTSTONE INTERBEDS
▤	SILTSTONE
░	SANDSTONE WITH MUDSTONE FLASERS
░	SANDSTONE:FINE GRAIN
▩	SANDSTONE:MEDIUM OR COARSE GRAIN
▒	SANDSTONE WITH MUDSTONE CLASTS
▆	TONSTEIN/BENTONITE
~~	SCOURED SURFACE

Figure 81. Legend of lithologies.

files consisted of one record for each described lithological unit. The hole identification, down hole depths to the top and bottom of each unit, lithology, grain size, and a visual estimate of the percentage of sand in the unit were entered in the appropriate computer fields. The data base package provided easy access to all data. Once all drill hole data was entered and edited, borehole columnar sections were plotted with the computer (Fig. 80). The Markov analysis and plotting programs were written by one of the authors (Kilby) to be compatible with the CAL DATA LTD. package.

Twelve lithologic units were used to describe Gething Formation core. These units are described following:

(1) SCG - coarse to medium-grained sandstone, relatively thick, high angle cross-stratified, frequently having a scoured basal contact. This unit shows a slight fining-up in grain size and a noticeable absence of burrowing. Laminae are commonly very faint and may often only be apparent due to concentration of carbonaceous debris along bedding planes. Reactivation surfaces are common.

(2) CGL - a mudstone pebble conglomerate. Clasts are of mudstone and often angular with a coarse or medium-grained sandstone matrix and occasional fossilized wood fragments. The clasts, which often show original primary bedding, usually have an imbricated structure and may occur in multiple bands each up to 3 centimetres thick.

(3) SFG - fine-grained sandstone has a sharp but not scoured basal contact and usually a fining-up gradational upper contact. Small-scale climbing ripples, and planar and ripple cross-lamination are the primary sedimentary structures. Soft sediment deformation appears as convoluted bedding, slumping, root growth, and burrowing. Evidence of water fluctuation in the form of reactivation surfaces and thin mud drapes are locally present. Fine-grained plant debris and coal spar is usually present along bedding planes.

(4) SMLF - sandstone with flaser bedding, is very fine to fine-grained, commonly silty, and ranges from simple to bifurcated wavy mud flasers. Up to 30 per cent of this unit is mudstone. Plant fossils are abundant on bedding planes. Moderate burrowing and rootlet growth cause colour mottling.

(5) SLT - siltstone showing faint to indistinct bedding that is commonly convoluted; slump structures and bioturbation are common. Fossilized plant remains are usually abundant. Uncommon small-scale planar cross-laminations and climbing ripples are present.

(6) MSF - mudstone with up to 50 per cent lenticular or wavy-bedded, silty to sandy intercalations. In wavy-bedded units, mud and sand layers alternate and form continuous layers. In lenticular-bedded units, sand lenses or ripples are discontinuous and isolated throughout the mudstone host. Some sandstone lenses show micro-crossbedding. Sedimentary structures present include horizontal and vertical burrows, load structures, and syneresis cracks. Syneresis cracks are postulated to result from changes in water salinity (Burst, 1965). Macerated plant debris is commonly present. Contacts are gradational.

(7) MNC - non-carbonaceous mudstone, massive to faintly laminated in more silty units. Plant debris and ironstone bands are rare. One interesting feature noted in one of these mudstone units is a thin pelecypod shell band that can be traced through several cores (Fig. 80). Bioturbation is normally very slight. Contacts are gradational to sharp.

(8) MC - carbonaceous mudstone found in association with coal seams in the stratigraphic sequence. Locally the mudstones contain coaly laminations or abundant macerated plant debris along bedding planes. Soft sediment deformation occurs mostly as rootlet penetration. Bioturbation is slight. Contacts with coal seams are abrupt; elsewhere contacts are generally gradational.

(9) MSL - mudstone with thin, flat sandstone streaks floating in a mudstone host. Less than 10 per cent sand is normally present. The unit is typically barren of plant debris and rootlets.

(10) COAL - coal displays dull to moderately bright lustre, reflecting the maceral content. Cleat development is good; and locally there is abundant pyrite on bedding planes or fractures surfaces.

(11) SMSI - interbedded sandstone, siltstone, and mudstone usually in less than 10-centimetre layers. The sandstones are fine grained with small-scale crossbedding, ripples, and flaser bedding; laminations are faint and often convoluted. Mudstones are generally silty. All three lithologies commonly contain abundant comminuted plant debris and low to moderate levels of bioturbation.

(12) ASH - tonsteins and bentonites are altered volcanic ash bands deposited in non-marine and marine facies, respectively. Tonsteins are kaolin rich; often they have a speckled appearance from the development of vermicular kaolinite (Kilby, 1984b). In core they are medium grey, have sharp contacts, can be scratched with a fingernail, and often contain coal spar and plant debris. Bentonites consist of clay-sized material, are light grey to greenish grey, break in poker-chip fashion, and often display low levels of bioturbation.

MARKOV PROCEDURES AND STANDARD SECTION DEVELOPMENT

The Markov procedures used in this study have borrowed heavily from techniques described by Siemers (1978) and Davis (1973). In this study units in individual holes were not numerous enough to provide meaningful results, so all holes were combined. The first step in this study was to count the number of transitions from one lithological unit to another in an upward direction. The count transition matrix (Fig. 82) displays the results of this procedure; 802 transitions were recorded from the 16 boreholes.

From the count transition matrix it was apparent that some transitions were more common than others, such as MC to COAL with 80 occurrences of this transition recorded. Note that these values do not take into account the relative amounts of each unit present. To examine this problem, following Siemer (1978), the expected matrix was calculated.

COUNT TRANSITION MATRIX

	COAL	MNC	MC	MSF	SLT	MSL	SFG	SCG	SMLF	CGL	SMSI	SCOR	TOTAL
COAL	0	39	57	11	13	4	2	3	9	0	4	2	144
MNC	14	0	21	14	16	5	16	12	18	2	2	10	130
MC	80	19	0	5	7	1	6	1	4	0	7	3	133
MSF	7	7	9	0	3	2	4	2	4	0	2	2	42
SLT	14	21	10	1	0	0	8	3	1	0	2	6	66
MSL	3	4	1	1	1	0	1	5	3	1	0	3	23
SFG	10	10	8	6	4	2	0	2	5	10	2	0	59
SCG	3	13	6	1	12	2	3	0	2	12	5	2	61
SMLF	7	12	14	1	6	5	1	0	0	1	2	4	53
CGL	0	2	0	0	0	0	10	15	2	0	1	1	31
SMSI	8	2	5	0	2	1	3	1	0	0	0	3	25
SCOR	0	0	1	1	2	1	6	15	4	5	0	0	35
TOTAL	146	129	132	41	66	23	60	59	52	31	27	36	802

EXPECTED MATRIX

	COAL	MNC	MC	MSF	SLT	MSL	SFG	SCG	SMLF	CGL	SMSI	SCOR
COAL	26	23	23	7	11	4	10	10	9	5	4	6
MNC	23	20	21	6	10	3	9	9	8	5	4	5
MC	24	21	21	6	10	3	9	9	8	5	4	5
MSF	7	6	6	2	3	1	3	3	2	1	1	1
SLT	12	10	10	3	5	1	4	4	4	2	2	2
MSL	4	3	3	1	1	0	1	1	1	0	0	1
SFG	10	9	9	3	4	1	4	4	3	2	1	2
SCG	11	9	10	3	5	1	4	4	3	2	2	2
SMLF	9	8	8	2	4	1	3	3	3	2	1	2
CGL	5	4	5	1	2	0	2	2	2	1	1	1
SMSI	4	4	4	1	2	0	1	1	1	0	0	1
SCOR	6	5	5	1	2	1	2	2	2	1	1	1

DIFFERENCE MATRIX

	COAL	MNC	MC	MSF	SLT	MSL	SFG	SCG	SMLF	CGL	SMSI	SCOR
COAL	-26	16	34	4	2	0	-8	-7	0	-5	0	-4
MNC	-9	-20	0	8	6	2	7	3	10	-3	-2	5
MC	56	-2	-21	-1	-3	-2	-3	-8	-4	-5	3	-2
MSF	0	1	3	-2	0	1	1	-1	2	-1	1	1
SLT	2	11	0	-2	-5	-1	4	-1	-3	-2	0	4
MSL	-1	1	-2	0	0	0	0	4	2	1	0	2
SFG	0	1	-1	3	0	1	-4	-2	2	8	1	-2
SCG	-8	4	-4	-2	7	1	-1	-4	-1	10	3	0
SMLF	-2	4	6	-1	2	4	-2	-3	-3	-1	1	2
CGL	-5	-2	-5	-1	-2	0	8	13	0	-1	0	0
SMSI	4	-2	1	-1	0	1	2	0	-1	0	0	2
SCOR	-6	-5	-4	0	0	0	4	13	2	4	-1	-1

Lithology	Total Thickness (metres)	No. of Units	Average Thickness (metres)
COAL	83.67	147	0.57
MNC	243.22	133	1.82
MC	78.42	136	0.57
MSF	67.57	42	1.61
SLT	105.65	68	1.55
MSL	38.30	23	1.66
SFG	101.20	60	1.68
SCG	116.76	62	1.88
SMLF	77.46	54	1.43
CGL	6.16	31	0.20
SMSI	81.83	27	3.03
SCOR	0.38	36	0.01

Figure 82. Count, expected, and difference matrices for Gething Formation sediments. Table summarizes abundance and average thickness of lithological units.

The values in this matrix were those expected if the succession of lithological states was perfectly random. Each element in this matrix was computed by cross-multiplying the count matrix row and column totals and dividing by the total number of transitions. This expected matrix was subtracted from the count transition matrix of observed transitions to produce a difference matrix (Fig. 82), that shows the differences between the observed and expected values. Positive elements in the difference matrix represent upward transitions that had a higher than random probability of occurring. Figure 82 also contains a tabulation of the number, total, and average thickness of the 12 units.

A refinement and expansion of the previously mentioned procedure was performed following Davis (1973). Five matrices were contructed; upward and downward transition probability matrices, upward and downward substitutability matrices, and a mutual substitutability matrix (Figs. 84 and 85). The upward transition probability matrix is a measure of how frequently a given unit is followed up section by another particular unit. It was calculated by dividing each element in each row of the count matrix by the total of the row; each row sums to one. The downward transition probability matrix is a measure of the frequency a given unit

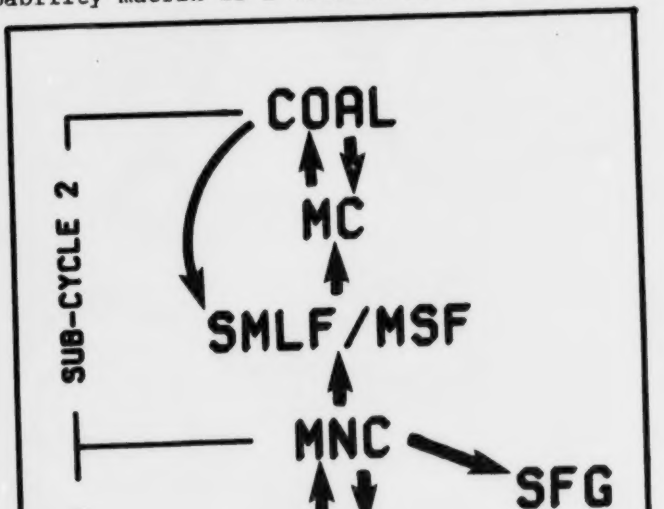


Figure 83. Transition flow diagram illustrating significant transitions on the basis of strongly positive values in the difference matrix.

UPWARD TRANSITION PROBABILITY MATRIX

	COAL	MNC	MC	MSF	SLT	MSL	SFG	SCG	SMLF	OGL	SMSI	SCOR
COAL	0	.27	.40	.08	.09	.03	.01	.02	.06	0	.03	.01
MNC	.11	0	.16	.11	.12	.04	.12	.09	.14	.02	.02	.08
MC	.60	.14	0	.04	.05	.01	.05	.01	.03	0	.05	.02
MSF	.17	.17	.21	0	.07	.05	.10	.05	.10	0	.05	.05
SLT	.21	.32	.15	.02	0	0	.12	.05	.02	0	.03	.09
MSL	.13	.17	.04	.04	.04		.04	.22	.13	.04	0	.13
SFG	.17	.17	.14	.10	.07	[illegible]	0	.03	.08	.17	.03	0
SCG	.05	.21	.10	.02	[illegible]	[illegible]	.05	0	.03	.20	.08	.03
SMLF	.13	.23	.26	.02	.11	.09	.02	0	0	.02	.04	.08
OGL	0	.06	0	0	0	0	.32	.48	.06	0	.03	.03
SMSI	.32	.08	.20	0	.08	.04	.12	.04	0	0	0	.12
SCOR	0	0	.03	.03	.06	.03	.17	.43	.11	.14	0	0

DOWNWARD TRANSITION PROBABILITY MATRIX

	COAL	MNC	MC	MSF	SLT	MSL	SFG	SCG	SMLF	OGL	SMSI	SCOR
COAL	0	.30	.43	.27	.20	.17	.03	.05	.17	0	.15	.06
MNC	.10	0	.16	.34	.24	.22	.27	.20	.35	.06	.07	.28
MC	.55	.15	0	.12	.11	.04	.10	.02	.08	0	.26	.08
MSF	.05	.05	.07	0	.05	.09	.07	.03	.08	0	.07	.06
SLT	.10	.16	.07	.02	0	0	.13	.05	.02	0	.07	.17
MSL	.02	.03	.01	.02	.02	0	.02	.08	.06	.03	0	.08
SFG	.07	.08	.06	.15	.06	.09	0	.03	.10	.32	.07	0
SCG	.02	.10	.05	.02	.18	.09	.05	0	.04	.39	.19	.06
SMLF	.05	.09	.11	.02	.09	.22	.02	0	0	.03	.07	.11
OGL	0	.02	0	0	0	0	.17	.25	.04	0	.04	.03
SMSI	.05	.02	.04	0	.03	.04	.05	.02	0	0	0	.08
SCOR	0	0	.01	.02	.03	.04	.10	.25	.08	.16	0	0

Figure 84. Upward and downward transition probability matrices.

was preceded by deposition of another particular unit. This factor was calculated from the count matrix by dividing each element in each column by the column total; each column of this matrix sums to one. The third, fourth, and fifth matrices are the substitutability matrices, they measure the degree of similarity between two units with respect to surrounding units. The upward substitutability matrix contains measures of similarity of any two lithologic units to be overlain by a similar lithological unit. The downward substitutability matrix is the same except the similarity is based on the tendency for two states to be underlain or preceded by a similar lithology. The upward substitutability matrix was calculated for each pair of lithologies by calculating the cross-product ratio of the respective rows. The downward substitutability matrix was calculated in the same manner but using columns instead of rows. The mutual substitutability matrix measures the degree to which two units are over and underlain by similar units. This matrix was obtained by multiplying the corresponding values from the upward and downward substitutability matrices.

A chi-square test was used to test the count transition matrix for the Markov property (Davis, 1973, p. 288). The null hypothesis stated that the observed transitions were independent of each other and therefore random. The alternative hypothesis was that they had a significant degree of dependency and thus formed a Markov chain. The statistic obtained was 854 with 120 degrees of freedom, therefore the null hypothesis was rejected with a confidence of at least 99.5 per cent; the sequence has a first order Markov property. With such a strong rejection, the possibility exists that higher order chains may be present; this hypothesis was not tested.

Attempts to obtain a representative sequence of lithological units descriptive of the major sedimentary pattern for the Gething Formation was made by a combination of traditional and automated techniques. Traditionally the difference matrix is interpreted and a schematic flow diagram constructed to illustrate the determined pattern of unit transitions. Figure 83 is such a diagram; it is based on the strongly positive difference values (highlighted) in the difference matrix (Fig. 82). This interpretation suggested a general fining upward depositional cycle composed of two fining up sub-cycles. The overall cycle in the Gething goes from a scour surface through successively finer grained sediments to coal. At the position of non-carbonaceous mudstone (MNC) the progression has about an even statistical chance of continuing on to finer grained sediments or cycling back into coarser grained material. When the progression passes MNC into the finer sediments, fining generally continues until COAL is encountered. Coal will in turn be followed by either carbonaceous mudstone or non-carbonaceous mudstone. The two sub-cycles are the coarse-grained cycle SCOR to MNC and the fine-grained, coal-bearing, cycle MNC to COAL. These two sequences are believed to represent fluvial (lateral accretionary) and overbank (vertical accretionary) deposits, respectively. The units SMSI and MSL were not

UPWARD SUBSTITUTABILITY MATRIX

DOWNWARD SUBSTITUTABILITY MATRIX

	COAL	MNC	MC	MSF	SLT	MSL	SFG	SCG	SMLF	CGL	SMSI	SCOR
COAL		.58	.16	.81	.69	.47	.67	.64	.89	.13	.52	.15
MNC	.47		.42	.78	.52	.68	.64	.51	.61	.48	.72	.56
MC	.14	.83		.61	.66	.51	.61	.33	.48	.09	.80	.06
MSF	.42	.61	.79		.87	.71	.78	.67	.91	.34	.86	.32
SLT	.43	.67	.77	.87		.73	.73	.62	.84	.33	.79	.21
MSL	.31	.62	.78	.79	.89		.68	.53	.56	.65	.61	.68
SFG	.46	.38	.42	.65	.66	.59		.81	.77	.16	.66	.33
SCG	.16	.21	.31	.48	.43	.42	.82		.74	.16	.48	.29
SMLF	.36	.48	.69	.94	.86	.78	.79	.66		.10	.77	.11
CGL	.12	.31	.20	.33	.53	.43	.26	.29	.36		.26	.91
SMSI	.77	.82	.56	.62	.79	.64	.55	.27	.56	.49		.23
SCOR	.47	.50	.54	.71	.74	.74	.84	.52	.77	.21	.58	

MUTUAL SUBSTITUTABILITY MATRIX

	COAL	MNC	MC	MSF	SLT	MSL	SFG	SCG	SMLF	CGL	SMSI	SCOR
COAL	1											
MNC	.28	1										
MC	.02	.34	1									
MSF	.34	.48	.48	1								
SLT	.30	.35	.51	.76	1							
MSL	.14	.42	.39	.56	.65	1						
SFG	.31	.25	.25	.51	.48	.40	1					
SCG	.10	.11	.10	.32	.27	.23	.67	1				
SMLF	.32	.30	.33	.86	.71	.44	.61	.49	1			
CGL	.02	.15	.02	.11	.18	.28	.04	.05	.04	1		
SMSI	.40	.59	.45	.53	.62	.39	.36	.13	.44	.13	1	
SCOR	.07	.28	.03	.23	.16	.50	.28	.15	.09	.20	-.13	1

Figure 85. Upward, downward, and mutual sutstitutability matrices for Gething sediments measured.

represented in this interpretation, due largely to the low number of transitions involving these units. The upward transition probability matrix (Fig. 84) is similar in some respects to the difference matrix (Fig. 82) but quite different in others. The probability matrix does not address the problem of the relative abundance of the units, however, it can be used to generate a representative stratigraphic pattern by a form of Monte Carlo simulation. In the simulation a starting unit was chosen, in this case SCOR, and on the basis of the probability values in the matrix the sequence of transitions determined. The first simulation was allowed to continue until all 12 sedimentary units were represented at least once. One thousand simulations were performed with the average length of section required to include all 12 units being 61 lithologic units. In most cases the last unit to be referenced was either SMSI or MSL due to the relatively low upward transition probabilities for both. In an effort to obtain a more compact sequence these two lithologic units were assumed to be a subset of larger unit and grouped with other similar units. Groupings were based on the mutual substitutability matrix (Fig. 85). As described earlier, two units which are strongly substitutable are overlain and underlain by similar units, and thus deposited in similar environments. Both SMSI and MSL were most closely matched with the siltstone (SLT) unit. The modified upward transition probability matrix was then utilized in another Monte Carlo simulation. The average section length in this case was 36 units. The simulation was then continued and 10 sequences of exactly 36 units were generated. The average number of each unit was then calculated from these 10 sequences to arrive at the number and type of units in the Monte Carlo standard section. Based on this simulation and the flow diagram (Fig. 83), a representative sequence was constructed (Fig. 86). The standard section is 36 units in length and contains four fining-up sub-cycles. For ease of unit identification the standard and simulated sequences displayed all units with the same thickness; Figure 82 contains a tabulation of the average unit thicknesses. The simulation confirmed the interpretation represented on Figure 83; the two sub-cycles are present and lithologies of the two do not mix. Sequence No. 2 of the standard section is an example of the complete, uninterrupted sequence from coarse-grained through finer grained sediments to coal.

DISCUSSION

Correlation of gross features is relatively straightforward on the correlation diagram (Fig. 80) and the Moosebar-Bluesky-Gething contacts are easily followed across the section. The bentonites in the lower Moosebar Formation are everywhere present and provide a time constraint to the diagram. The thickness between these bentonites and the top of the Gething Formation increases to the east, suggesting marine deposition in the east and active coal swamps in the west. The Bluesky marker interval increases in thickness from the west to the east. Column 15 (Fig. 80) contains a very large thickness of sandstone believed to be Bluesky. The Bluesky Formation in the subsurface of Alberta and

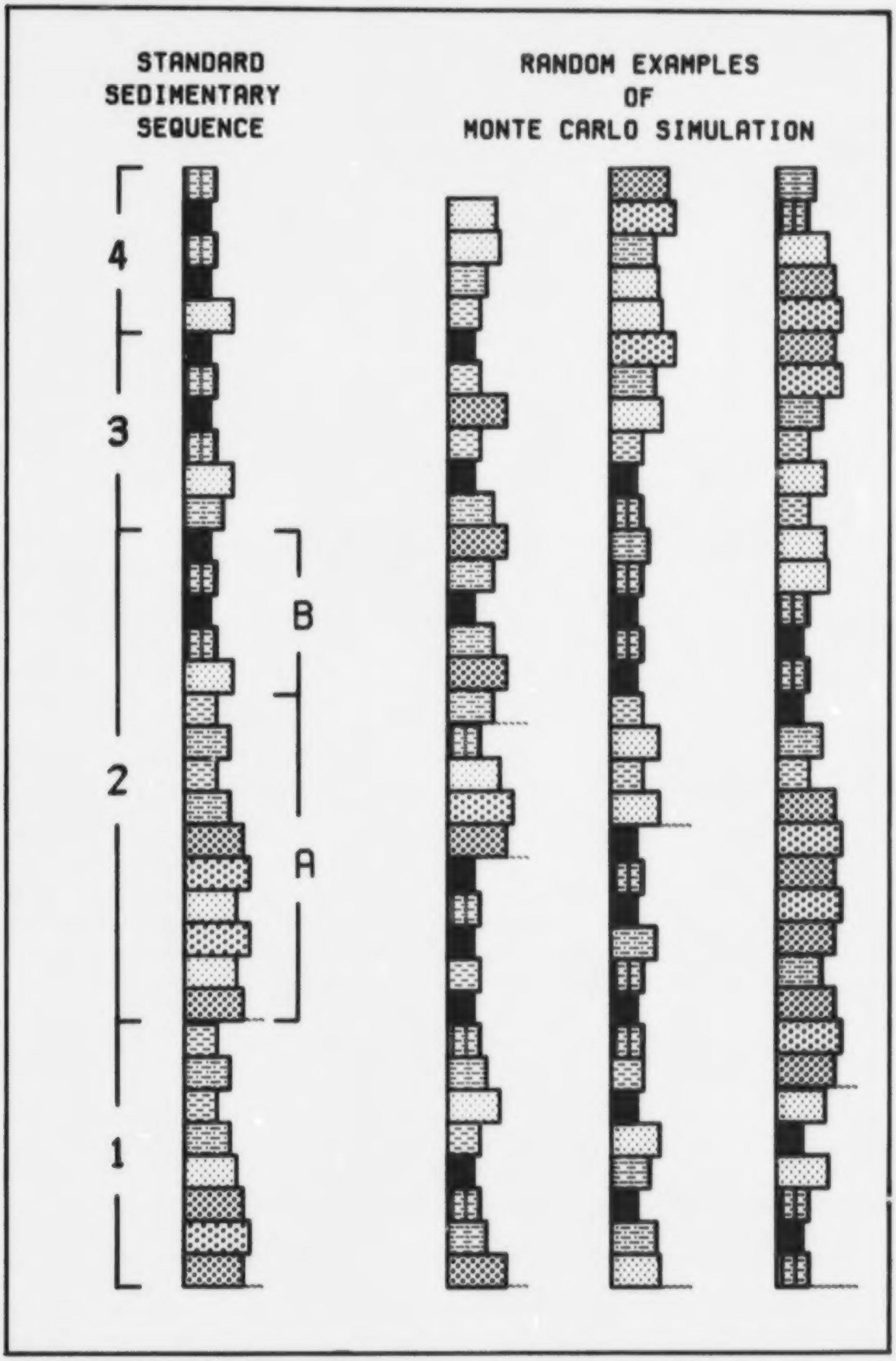

STANDARD SEDIMENTARY SEQUENCE
RANDOM EXAMPLES OF MONTE CARLO SIMULATION
4
3
2
1
B
A

Figure 86. Derived standard sedimentary sequence for the upper Gething formation based on a Monte Carlo simulation of the upward transition probability matrix.

northeastern British Columbia is of a similar thickness; conceivably the section contains the transition zone from what is referred to as Bluesky on the coal properties of the Foothills to the formal Bluesky Formation in the subsurface.

Correlation of Gething strata is difficult. Coal seams can be correlated across several holes but, with the exception of the Trojan seam, individual seams are not laterally continuous on this section. The Trojan seam has been tentatively correlated across much of the western portion of the section. Tonsteins seem to be erratic, but this is not the case in reality. Two of the major zones have been correlated as far as 120 kilometres southward to the Sukunka region. Apparently significant numbers of these bands were removed from the core with the coal intervals during sampling thus limiting their usefulness in this study. A major mudstone zone, approximately 10 metres thick, has been correlated across the section. In some cases this correlation is tenuous, but in others the presence of a coquina band in several holes strengthened the correlation. Structure has also complicated borehole correlations. Fault duplicated sections were noted in outcrop sections, and geophysical logs show several duplicated intervals in the holes presented here. Resolution of the structure has not yet been attempted. Despite structural complications, several prominent zones were correlatable over significant distances.

The Monte Carlo standard section for the Gething Formation depicts two sub-cycles and one large cycle made up of the combination of two sub-cycles. The coarse-grained sediments represent active meandering stream deposits. The lower cycle (Fig. 86) consists of thick, fining-up, laterally accreted sandstone channel fill with a scoured base and lag deposits and ends with silts and non-carbonaceous mudstones. The finer, coal-bearing cycle represents vertically accreted floodplain deposits with well to poorly drained swamps and peat swamps and channel margin levee deposits. Episodic crevasse splay deposits comprise a third, minor cycle which can enter the floodplain cycle at any point (not represented on the standard section).

Typical meandering stream channels erode on the concave side and deposit on the convex portion of each meander, point bar. This combination produces a tabular sand unit overlying a near horizontal erosion surface, with or without lag deposits. Point bar deposits are commonly overlain by finer grained floodplain deposits. In this study lithological units associated with this environment would be SCOR, CGL, SCG, SFG, and SLT, with MNC representing the overlying fine-grained flood deposits.

With channel migration, substantial flood basin sedimentation, consisting of vertically accreted deposits in the interdistributary areas, is initiated. Flood plains act as settling basins in which long-continued accumulations of fine-grained suspended sediments are derived from overbank flows (Reineck and Singh, 1980). In well-drained swamps periodical subaerial exposure oxidizes sediments, destroying the organic matter. Non-carbonaceous mudstones (MNC) often seen in the section may represent this setting. In stagnant waters reducing conditions preserve organic matter, creating carbonaceous muds (MC). Continued accumulation of the organic matter results in thick vegetation growth that leads to peat development and the beginning of coal swamps. The association of mudstones and coals is demonstrated in the difference, upward and downward transition probability matrices where MC and COAL have high transition measures.

CONCLUSION

Examination of the upper portion of the Gething Formation along the Peace River has only begun. More work is needed to sort out the structural problems and to attempt detailed correlations to facilitate understanding of the depositional history of this area and document the areal distribution of the various facies. The study to date has:

(1) demonstrated the presence of potentially powerful marker horizons;

(2) shown the presence of a strong preferred ordering in the sedimentary sequence; and

(3) illustrated the time relationship of the Gething-Bluesky-Moosebar contacts in this area.

ACKNOWLEDGMENTS

The authors would like to thank Dr. D. W. Gibson of the Geological Survey of Canada for useful discussion during core logging and K. Clark of the Ministry of Energy, Mines and Petroleum Resources for excellent service at the Charlie Lake core facility.

REFERENCES

Burst, J. F. (1965): Subaqueously Formed Shrinkage Cracks in Clay, *Jour. Sed. Petrol.*, Vol. 35, No. 2, pp. 348-353.

Davis, J. C. (1973): Statistics and Data Analysis in Geology, *John Wiley and Sons*, New York, 550 pp.

Kilby, W. E. (1984a): The Character of the Bluesky Formation in the Foothills of Northeastern British Columbia (930, P, I), *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1983, Paper 1984-1, pp. 109-112.

.... (1984b): Tonsteins and Bentonites in Northeast British Columbia (930, P, I), *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1983, Paper 1984-1, pp. 95-107.

Reineck, H. E. and Singh, I. B. (1980): Depositional Sedimentary Environments with Reference to Terrigenous Clastics, *Springer-Verlag*, New York, 549 pp.

Siemers, C. T. (1978): Generation of a Simplified Working Depositional Model for Repetitive Coal Bearing Sequences Using Field Data: An Example from the Upper Creatceous Menefee Formation (Mesaverde Group), Northwestern New Mexico, *in* Proceedings of the Second Symposium on the Geology of Rocky Mountain Coal, H. E. Hodgson, editor, *Colorado Geol. Surv.*, pp. 1-22.

Stott, D. F. (1975): The Cretaceous System in Northeastern British Columbia, *in* The Cretaceous System in the Western Interior of North America, W.G.E. Caldwell, editor, *Geol. Assoc. Can.*, Special Paper 13, pp. 441-467.

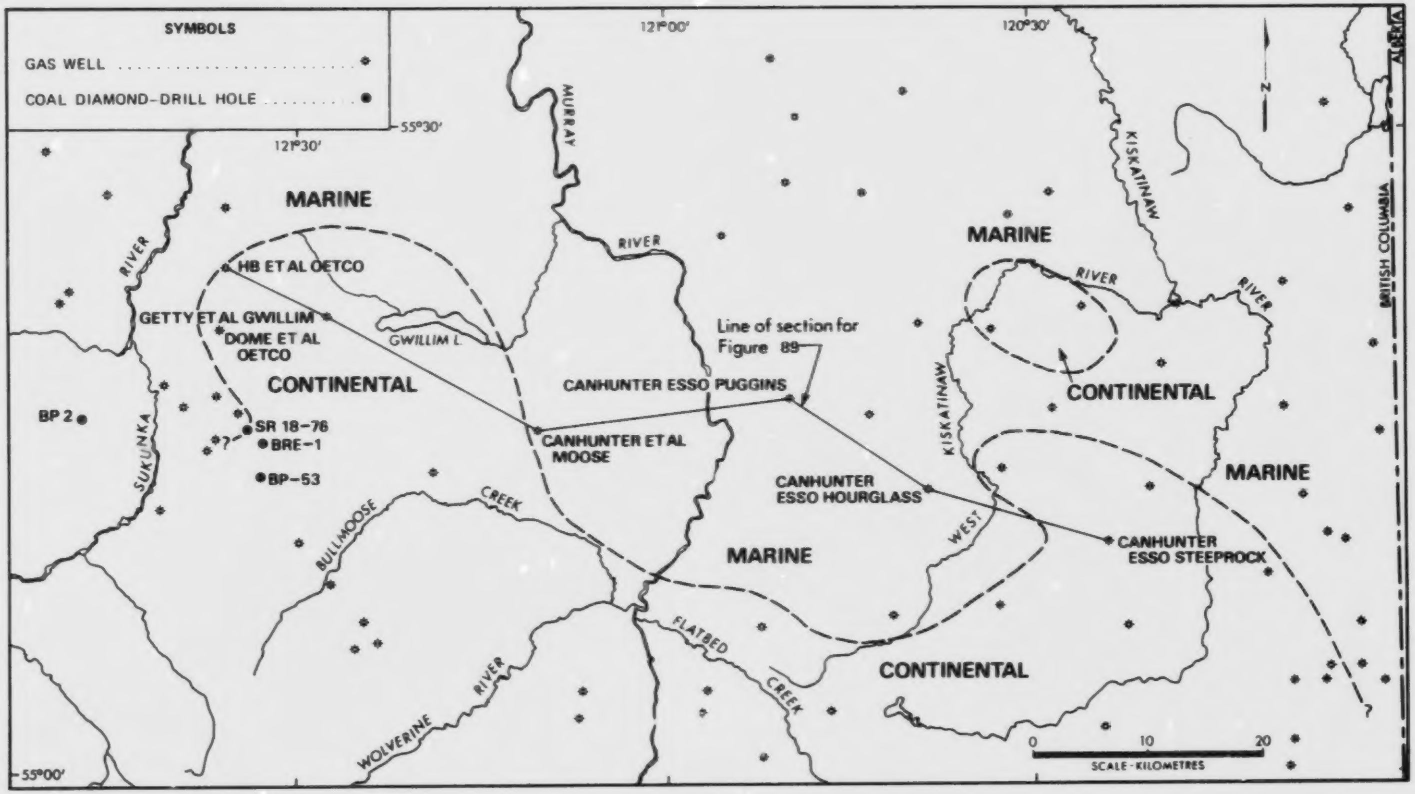

SYMBOLS
GAS WELL
COAL DIAMOND-DRILL HOLE
55°30'
55°00'
121°30'
121°00'
120°30'
N
ALBERTA
BRITISH COLUMBIA
MARINE
MARINE
MARINE
MARINE
CONTINENTAL
CONTINENTAL
CONTINENTAL
HB ET AL OETCO
GETTY ET AL GWILLIM
DOME ET AL OETCO
GWILLIM L.
SR 18-76
BRE-1
BP-53
BP 2
?
MURRAY
RIVER
RIVER
RIVER
RIVER
KISKATINAW
KISKATINAW
WEST
SUKUNKA
BULLMOOSE
CREEK
WOLVERINE
RIVER
FLATBED
CREEK
Line of section for Figure 89
CANHUNTER ESSO PUGGINS
CANHUNTER ET AL MOOSE
CANHUNTER ESSO HOURGLASS
CANHUNTER ESSO STEEPROCK
0
10
20
SCALE-KILOMETRES

Figure 87. Eastern limit of upper coal measures of Gething Formation (Chamberlain member).

EASTERN LIMIT OF UPPER COAL MEASURES OF THE GETHING FORMATION
(CHAMBERLAIN MEMBER)
PEACE RIVER COALFIELD
(93P)

By A. Legun

INTRODUCTION

In a recent correlation of Lower Cretaceous coal measures in the Peace River Coalfield, Duff and Gilchrist (1983) documented the presence of a major marine tongue in the Gething Formation. The marine tongue separates the Gething Formation into upper and lower coal measures for an area extending southeastward from the Sukuna River (Fig. 87). Northwest of the Sukunka River the upper coal measures pinch out and the marine tongue passes laterally into the Moosebar Formation. To the southeast at Kinuseo Creek the marine tongue pinches out and upper and lower coal measures merge (Fig. 88). The upper coal measures of the Gething Formation are termed Chamberlain member by Duff and Gilchrist (1983).

Examination by the writer of additional coal drill hole data, together with gas and oil well data from the plains, support the Duff and Gilchrist correlations and tentatively define the areal limits of the Chamberlain member in the Sukunka-Gwillim Lake area (Legun, 1984). A delta-like lobe was delineated which pinched out both to the north and east against marine units. Work this year was focused on tracing the marine boundary of the Chamberlain member to the southeast of Gwillim Lake. The work was facilitated by the B.Sc. thesis of Williams (1984) on the Bluesky Formation of the plains.

The Bluesky, as defined by Williams and oil company geologists, corresponds to the interval between lower coal measures of the Gething Formation, and the Moosebar Formation; therefore it includes the marine tongue, Chamberlain member, and its lateral (marine) equivalents (*see* Fig. 88). Williams subdivided the Bluesky into a number of units based on geophysical signature. Her continental unit, B1, is roughly equivalent to the Chamberlain member, though it is isopached into areas where no coal is present.

This writer reviewed Williams' work and reinterpreted the eastern limit of the upper coal measures based on the presence or absence of coal. Results are shown on Figure 87. The figure shows the boundary to continue east-southeast from the Gwillim Lake area, swing toward the north in the vicinity of West Kiskatinaw River, then revert to a southeast trend near Kiskatinaw River. This boundary indicates the maximum eastern extension of continental deposits (delta and coastal plain) into the Moosebar Sea during regression.

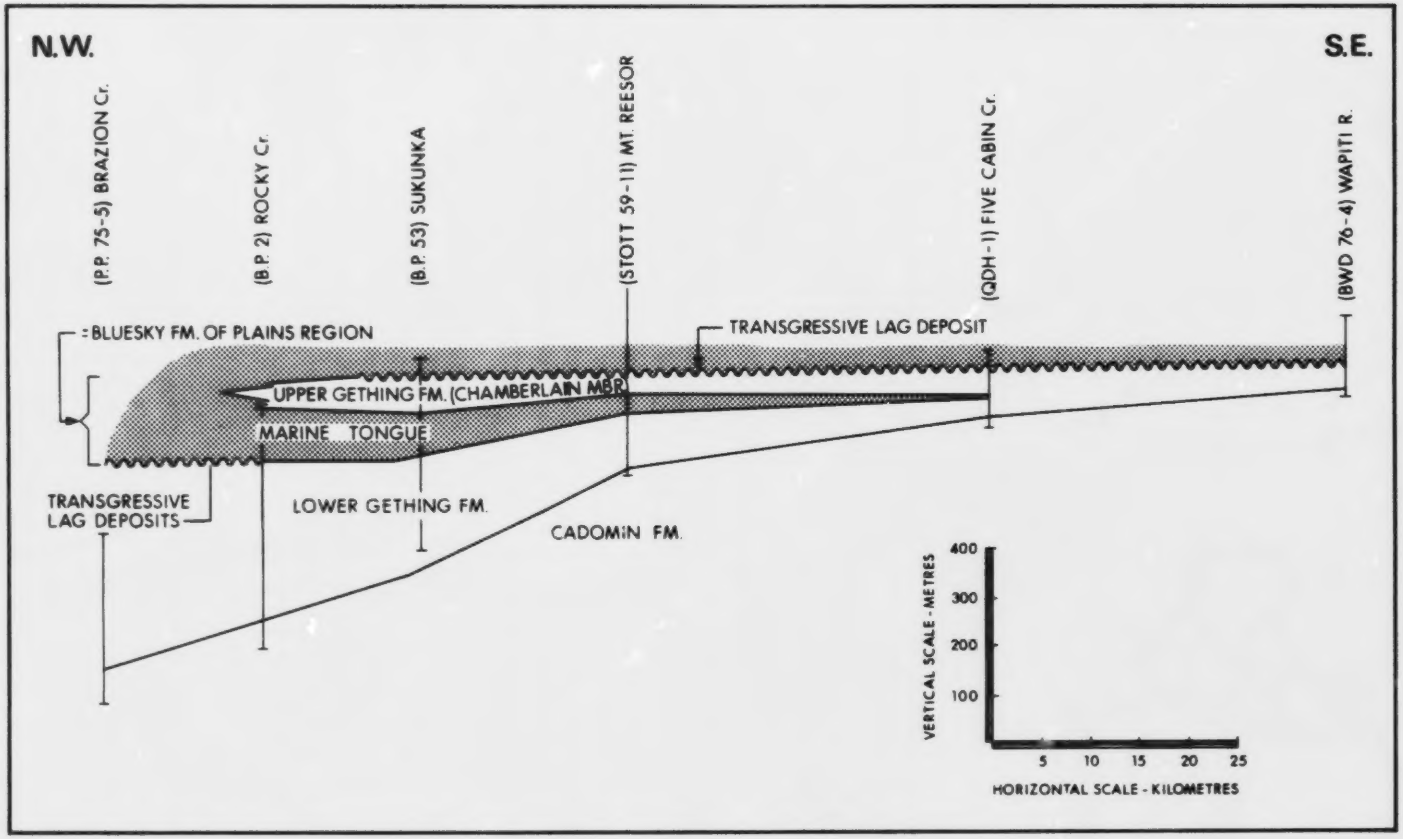

N.W.
S.E.
(P.P. 75-5) BRAZION Cr.
(B.P. 2) ROCKY Cr.
(B.P. 53) SUKUNKA
(STOTT 59-11) MT. REESOR
(QDH-1) FIVE CABIN Cr.
(BWD 76-4) WAPITI R.
= BLUESKY FM. OF PLAINS REGION
TRANSGRESSIVE LAG DEPOSIT
UPPER GETHING FM. (CHAMBERLAIN MBR)
MARINE TONGUE
TRANSGRESSIVE LAG DEPOSITS
LOWER GETHING FM.
CADOMIN FM.
VERTICAL SCALE - METRES
400
300
200
100
5
10
15
20
25
HORIZONTAL SCALE - KILOMETRES

Figure 88. Northwest-southeast line of section showing relationship of marine tongue to Gething Formation coal measures in the Peace River coalfield (modified after Legun, 1984).

In the Getty et al Gwillim well, Williams failed to recognize the upper coal measures (Chamberlain member) and the great thickness (110 metres) of marine tongue below. Only 20 metres is designated as marine tongue (Williams' unit B) and traced to the north in section A-A'. As a result, Williams' unit B of the Bluesky corresponds with the marine tongue of Duff and Gilchrist only in the eastern portion of her study area. In the west the true marine tongue (which includes her Spirit River No. 4 unit in section A-A') passes into Moosebar Formation shales northward, as it does in the Northeast Coalfield. The geophysical trace of Chamberlain member equivalents in the Peace River area is well within the Moosebar Formation, 85 metres above its base.

To confirm correlations and rapid thickening of the marine tongue to the west, a line of section from Canhunter Esso Steeprock to HB et al Oetco is presented (Fig. 89). At Canhunter Esso Steeprock the marine tongue is thin (35 metres), upward coarsening, and bounded by coal measures. The tongue has thickened at Canhunter Esso Puggins and Canhunter et al Moose but there are no overlying coal measures; these well localities correspond to positions east of the marine/continental boundary on Figure 87. Upper coal measures reappear at Getty et al Gwillim but are on the point of pinching out at HB et al Oetco where the marine tongue is 150 metres thick. To the southwest, in the coalfield, Duff and Gilchrist show 120 metres of marine tongue in diamond-drill hole BP-53.

Northwest of HB et al Oetco, the geophysical trace of upper coal measure equivalents within Moosebar Formation shales can be traced in drill holes and well logs to the Peace River Canyon area, where they lie some 115 metres above the base of the Moosebar Formation. Continuing work by Kilby (1984) on tonstein markers in the Moosebar Formation should verify this correlation.

DEPOSITIONAL HISTORY

A marine transgression penetrated southward and drowned coastal and deltaic peat environments represented by the Lower Gething Formation. The western position of the shoreline at this time is not known and may have been in eroded terrane west of the coalfield. By the time marine waters reached their southern limits of extension at Kinuseo Creek, a considerable amount of marine sediment (85 to 115 metres) had been deposited in the Peace River area to the north.

A localized regression followed due to increased sediment supply in the study area. This is reflected in the coarsening upward (that is, shallowing) nature of marine deposits in the Moosebar embayment. Continental deposits prograded to the east and a wide coastal-deltaic plain extended from Gwillim Lake east-southeastward to beyond the Alberta border. Peat environments in the plain formed future coal measures of the Chamberlain member at this time. The plain did not extend north of the Sukunka River; the shoreline probably swung to the west and the embayment widened northward.

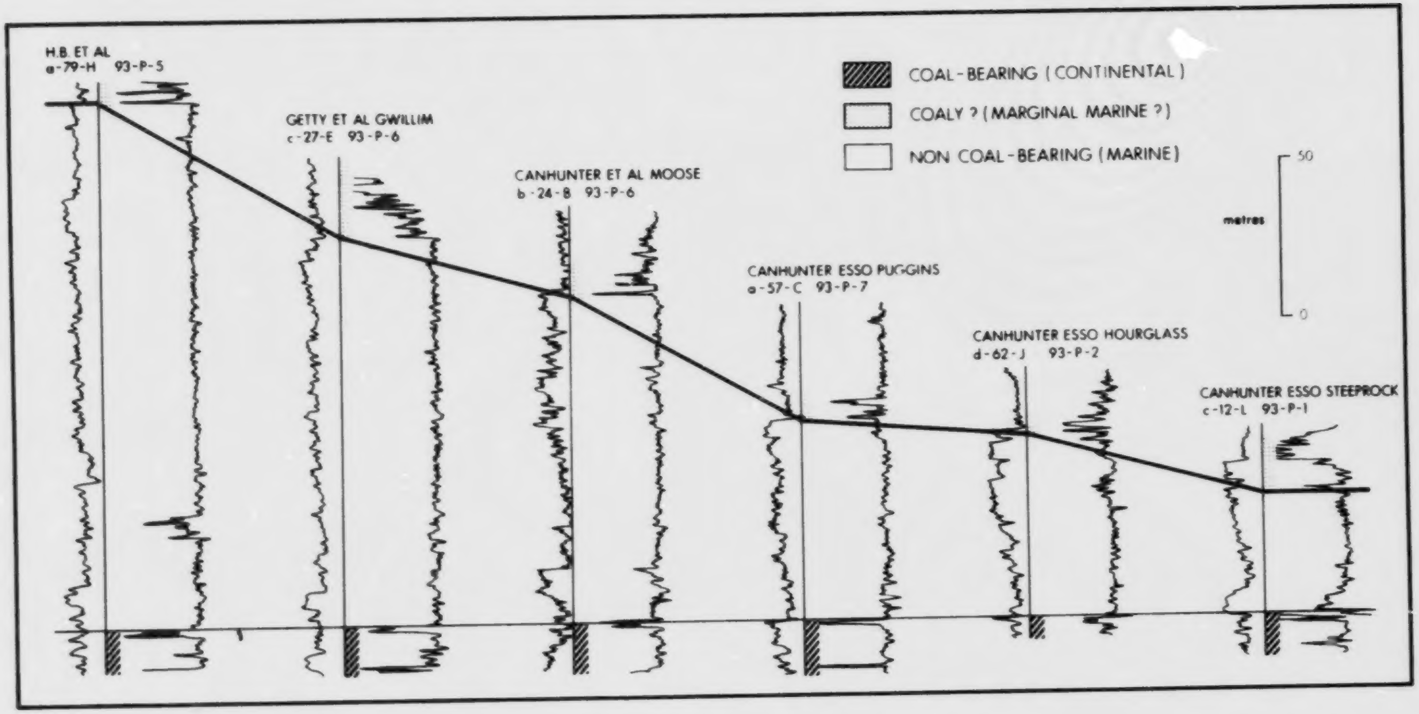


Figure 89. Correlation of marine tongue, upper and lower member of the Gething Formation (for line of section, see Fig. 87).

This rather localized regression was followed by the principal transgression of the Moosebar Sea. The sea drowned coastal and deltaic deposits of the Chamberlain member and the shoreline retreated far to the west. To the southeast marine waters extended into Alberta.

REFERENCES

Duff, P.McL.D. and Gilchrist, R. D. (1983): Correlation of Lower Cretaceous Coal Measures, Peace River Coalfield, British Columbia, *B.C. Ministry of Energy, Mines & Pet. Res.*, Paper 1981-3, 31 pp.

Kilby, W. E. (1984): Tonsteins and Bentonites in Northeast British Columbia (930, P, I), *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1983, Paper 1984-1, pp. 95-107.

Legun, A. (1984): Stratigraphic and Depositional Relationships between the Bluesky Marker Unit, Gething Marine Tongue, and Upper Coal Measures of the Gething Formation (930, P), *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1983, Paper 1984-1, pp. 117-122.

Williams, C. (1984): The Bluesky Formation of Northeastern British Columba: Depositional History and Stratigraphy, B.Sc. thesis, *Univ. of Calgary*, 32 pp.

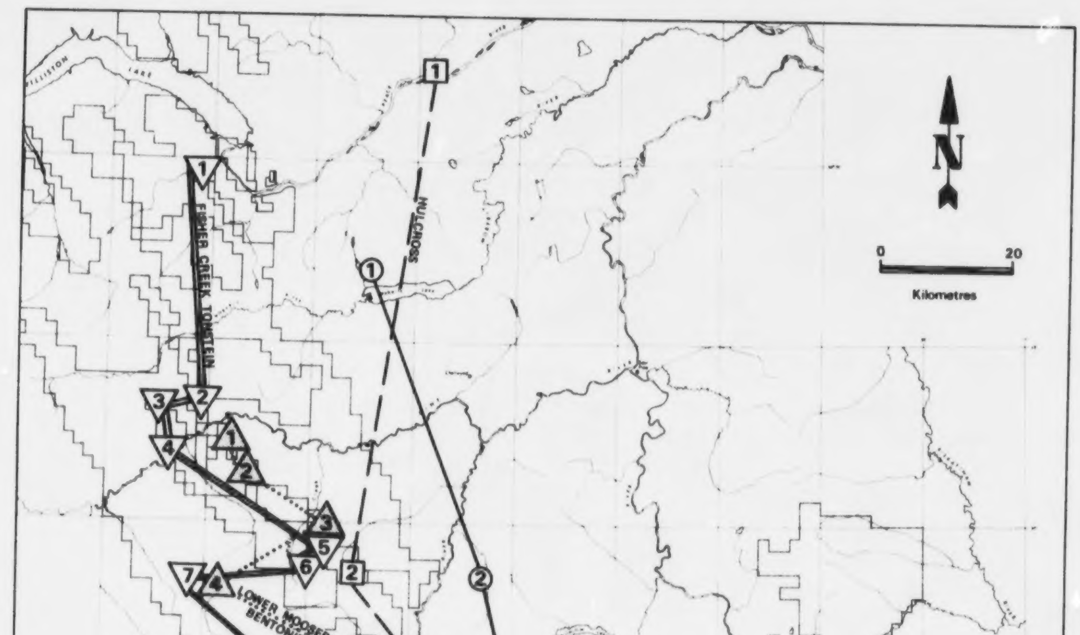

WILLISTON LAKE
N
0
20
Kilometres
FISHER CREEK TONSTEIN
HULCROSS
LOWER MOOSEBAR BENTONITES
TWIN BENTONITES
1
2
3
4
5
6
7
8
FIGURE 91 LOCATIONS
HULCROSS; FIGURE 92 LOCATIONS
TWIN BENTONITES; FIGURE 93 LOCATIONS
LOWER MOOSEBAR BENTONITES; FIGURE 94 LOCATIONS
FISHER CREEK TONSTEIN; FIGURE 95 LOCATIONS

Figure 90. Location map of borehole sites used in the tonstein and bentonite correlation examples. Section lines indicate the order in which the holes appear on the various sections.

TONSTEIN AND BENTONITE CORRELATIONS IN NORTHEAST BRITISH COLUMBIA
(930, P, I; 94A)

By W. E. Kilby

INTRODUCTION

Examination and correlation of tonsetins and bentonites was continued in northeastern British Columbia during the 1984 field season. Correlation distances were doubled for several of the previously identified tonstein horizons. Samples were collected for radiometric age dating. Several formation contacts were examined on a regional scale with respect to tonstein and bentonite horizons. Chemical data became available for 58 samples. Preliminary statistical analysis of this data was encouraging for correlation purposes. Mineralogical (XRD) results also appear to hold promise as a correlation tool.

REGIONAL CORRELATIONS

Volcanic ash falls, by their nature, cover large areas. Given the proper low energy depositional environment the resultant tonsteins and bentonites can be present over large distances. Three previously described zones (Kilby, 1984) were examined and have had their correlatable distances considerably extended. Ash bands in the Hulcross, Moosebar, and Gething Formations were used to gain an understanding of the diachronous nature of several formational contacts. A series of sections through the various horizons is presented below, the areal and stratigraphic positions of these sections are given on Figures 90 and 91.

HULCROSS

Prominent bentonite bands in the lower Hulcross Formation are exposed on the edge of Highway 29 along the Peace River east of Hudson's Hope; one 40-metre section in this area contained 17 bentonite horizons. A bentonite band located at the junction of Farrel Creek and the Peace River was sampled for radiometric age dating. This sample is presently undergoing analysis at the University of Alberta. A borehole drilled near this position encountered four prominent bentonite bands in the lower Hulcross. Examination of geophysical logs through this interval at widely spaced locations showed these four bands to be continuous over a considerable distance. Figure 92 is a display of geophysical logs from three widely spaced holes illustrating the relationship between the isochronous bentonite bands and the diachronous Hulcross-Gates contact. Several of these horizons were sampled and the correlation will be tested as chemical and mineralogical data become available. Examination of the

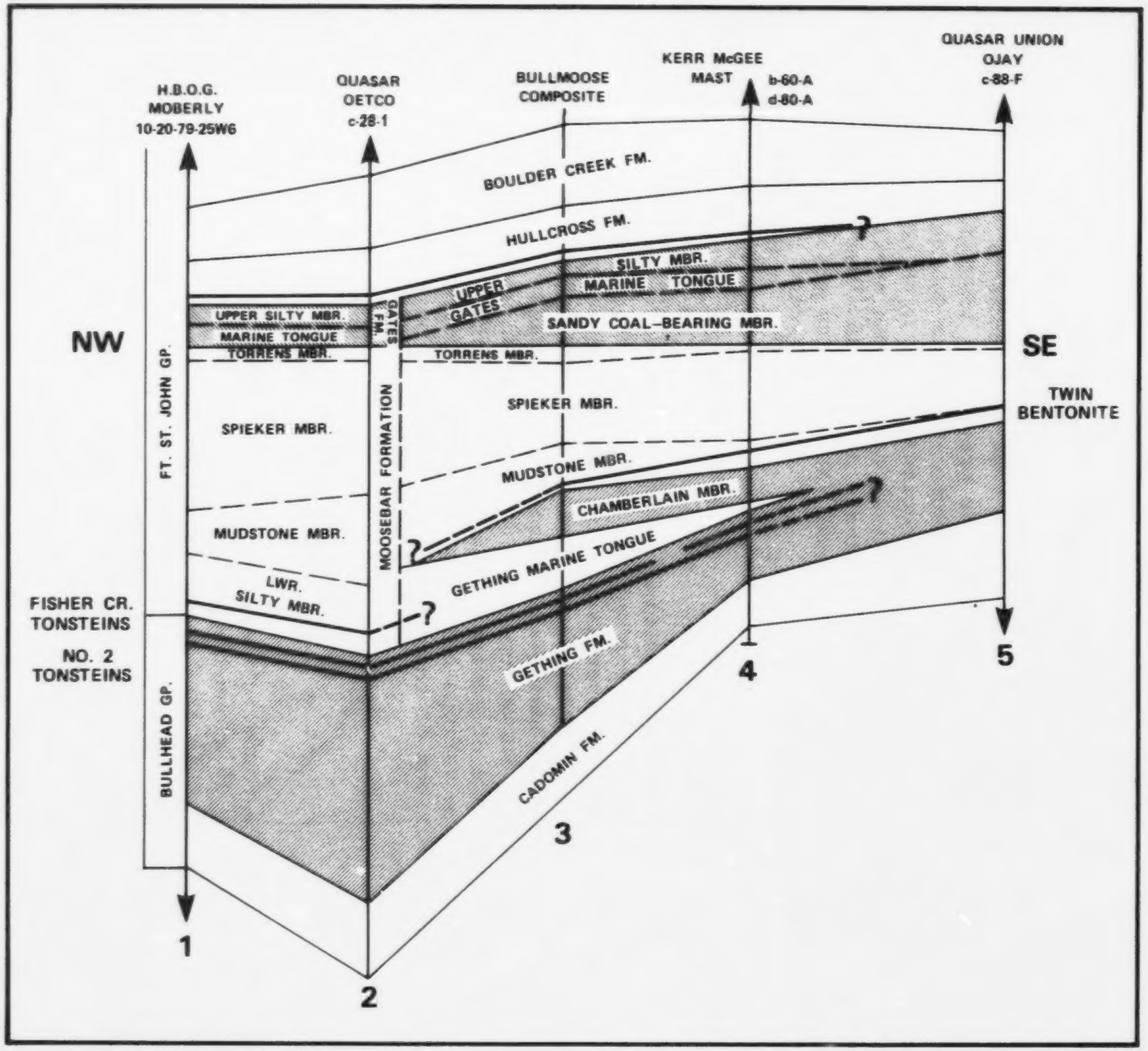

H.B.O.G.
MOBERLY
10-20-79-25W6
QUASAR
OETCO
c-28-1
BULLMOOSE
COMPOSITE
KERR McGEE
MAST
b-60-A
d-80-A
QUASAR UNION
OJAY
c-88-F
NW
SE
FT. ST. JOHN GP.
BULLHEAD GP.
BOULDER CREEK FM.
HULLCROSS FM.
UPPER SILTY MBR.
MARINE TONGUE
TORRENS MBR.
GATES FM.
UPPER GATES
SILTY MBR.
MARINE TONGUE
SANDY COAL-BEARING MBR.
TORRENS MBR.
MOOSEBAR FORMATION
SPIEKER MBR.
SPIEKER MBR.
MUDSTONE MBR.
MUDSTONE MBR.
CHAMBERLAIN MBR.
LWR. SILTY MBR.
GETHING MARINE TONGUE
GETHING FM.
CADOMIN FM.
TWIN BENTONITE
FISHER CR. TONSTEINS
NO. 2 TONSTEINS
?
?
?
?
1
2
3
4
5

Figure 91. Schematic regional stratigraphic section illustrating the position and extent of major ash horizons examined in this study (modified after Duff and Gilchrist, 1981). Section position given on Figure 90.

sections show that at the time the lowest of the four ash bands was being deposited marine conditions had existed for a considerable time in the area of hole number 1 to the north, but in the area of hole number 3, coal swamp facies had just been replaced by marine sedimentation. The thickness of the intervening mudstone suggests that sedimentation rates appear almost constant over the length of this section during the time encompassed by these four bands.

MOOSEBAR

Bentonite horizons have previously been recognized in the Moosebar Formation from Peace River to the Grande Cache area of Alberta. Duff and Gilchrist (1981) correlated two prominent bands in the Bullmoose-Sukunka area. Two prominent bentonites have been used by workers in the Monkman area to sort out structural problems. A series of bentonites have been correlated in the Goodrich-Pine Pass area and a persistant series of thin bentonites are present along the Peace River (Kilby and Oppelt, this volume).

In the Peace River area a series of up to four bentonite bands are located about 10 metres above the Gething-Moosebar contact, or Bluesky (N) unit. These horizons have been traced more than 100 kilometres in an east-west direction (Kilby and Oppelt, this volume, *see* Fig. 80). A marked decrease occurs in the stratigraphic distance between these bentonites and the top of the Gething Formation in a westerly direction. In the west in borehole 1, the bentonites are in contact with siltstones, possibly of the Gething Formation, while to the east they are well above the Gething Formation. This coarser grained material, if not Gething Formation strata, at least suggests proximity to a shoreline or sediment source. A relatively constant thickness between the bentonite and Gething Formation is present from boreholes 2 to 23 while over, but from boreholes 13 to 14 a similar distance, the interval thickness quadruples. This significant thickness increase and the decrease in coal content in the underlying Gething Formation suggest that this area coincided with a break in facies in late Gething time.

In the Sukunka River to Belcourt Creek area two prominent bentonite horizons occur in the lower Moosebar Formation. These bentonites, referred to as the Twin Bentonites (Kilby, 1984), have been correlated over a distance of nearly 100 kilometres (Fig. 93) and the correlation is open at both ends. Figure 93 contains three borehole geophysical logs of these bentonites and the Moosebar-Gething contact. The constant thickness between the bands suggests a constant sedimentation rate over the area at the time of the ash falls. Also apparent is convergence of the bentonites and the Gething Formation in a northward direction. This relationship implies that coal swamps were present in the Sukunka area while marine Moosebar sedimentation was occurring to the south. As it is generally accepted that the Clearwater Sea transgressed in a southerly direction there must have been an embayment south of Sukunka or

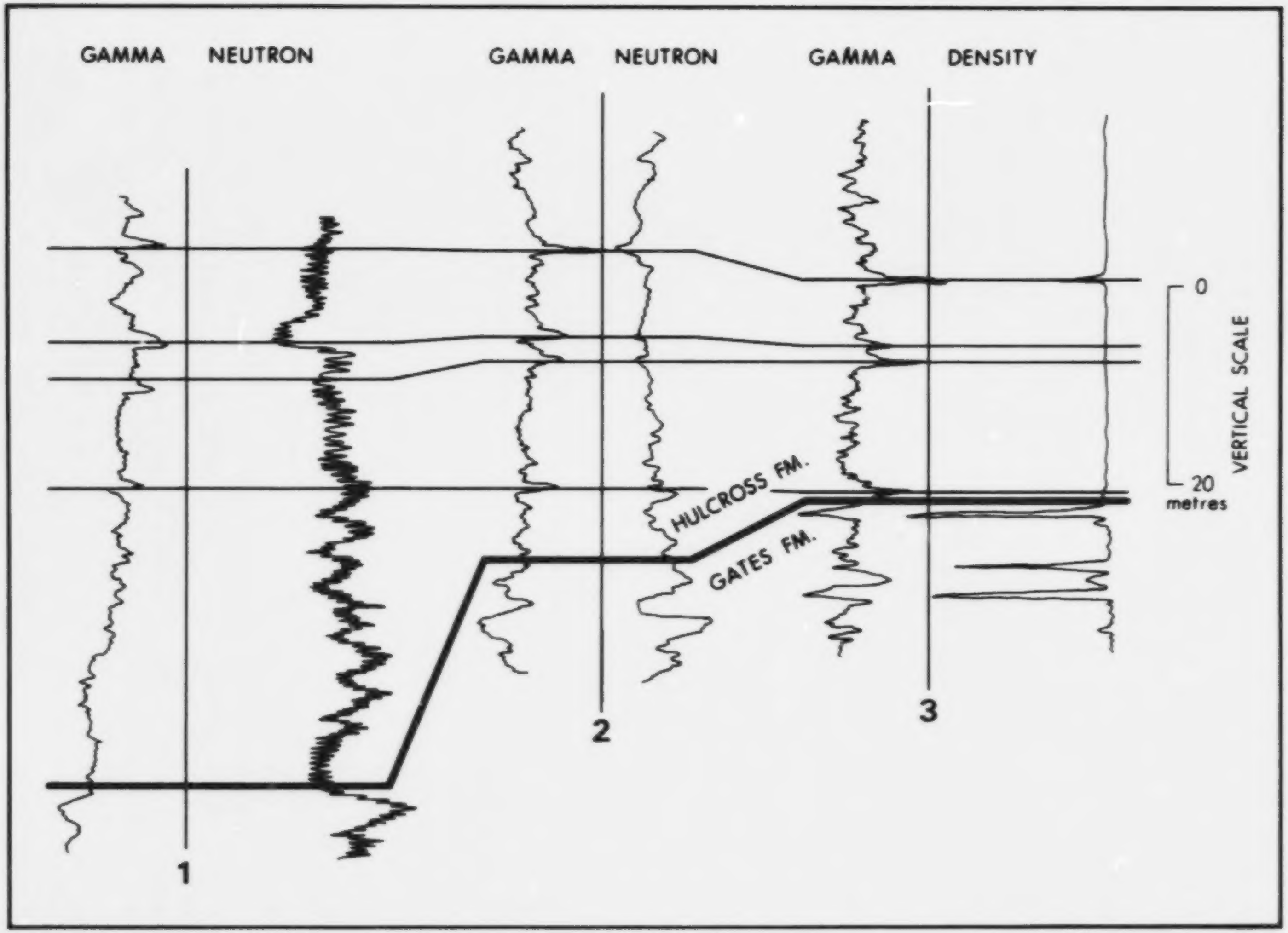


Figure 92. Bentonites in the lower Hulcross Formation. Bentonites appear as strong gamma responses (deflections to the right). See Figure 90 for location.

alternatively the Sukunka area formed a projection seaward (eastward), possibly in the form of a delta, during the early phases of the marine transgression. Duff and Gilchrist (1981) tentatively correlated these bentonite horizons with two bentonites in the Peace River area. This is a considerable distance with no intermediate data locations to reinforce the interpretation therefore this correlation remains questionable at this time.

In the Goodrich area, between the Pine River and Brazion Creek, a series of prominent bentonite horizons ocur within the lower 50 metres of the Moosebar Formation. These bands have been used by company workers in the area and are traceable over a considerable distance. Figure 94 displays a tentative correlation of these horizons between the Pine and Sukunka Rivers. The possibility exists that these bentonites correlate with those discussed earlier along the Peace River. These correlations are strongly influenced by the distinctive nature of the Bluesky (N) unit (Kilby, 1984a). This unit is persistent from the Peace River to South of the Sukunka River. The three members of the unit from the base up are: a thin conglomerate or conglomeratic unit; a turbiditic, coarsening-up, bioturbated, silty mudstone; and a glauconitic mudstone or glauconite sand interval. This unit is readily distinguishable in boreholes and well-exposed outcrop sections. In the south it is overlain by the Upper Gething and forms the basal part of the Moosebar Marine tongue of Duff and Gilchrist (1981).

The Fisher Creek Tonstein zone (Kilby, 1984b) was traced both northward and southward (Fig. 95). Examination of the Gething section along Moosebar Creek yielded a fault repeated occurrence of the Fisher Creek Tonstein whose identity was confirmed by the presence of the No. 2 Tonstein 30 metres stratigraphically below it; Kilby (1984b, Fig. 38b) suggested this possibility. Examination of borehole geophysical and lithological logs from the Sukunka and Quintette areas indicates the presence of tonsteins in the proper position to match the Fisher Creek and No. 2 intervals. The Gething Formation north of Burnt-Sukunka Rivers is equivalent to the Lower Gething of the Sukunka region. The Upper Gething of the Sukunka area contains locally well-known coal seams such as the Bird, Chamberlain, and Skeeter; it has no expression north of the Burnt-Sukunka area. The Fisher Creek Tonstein, No. 2 Tonstein, and Bluesky (N) are all parallel and approximately 30 metres apart over the Peace to Sukunka River area. This association is very useful in correlating sections from the many properties. It can now be shown that the following seams were being deposited at the time the Fisher Creek Tonstein fell: Trojan Seam in the Peace River area; No. 1 Seam at Willow Creek; E Seam at Noman Creek; Brenda Seam at Falling Creek; No. 1 Seam at Goodrich; and B Seam at Sukunka.

Excellent exposures of the Bluesky (N) and Fisher Creek Tonstein zone occur on an exploration road along Chamberlain Creek. The Fisher Creek Tonstein was sampled for radiometric age dating along Fisher Creek and is presently being processed. This data and those obtained from the

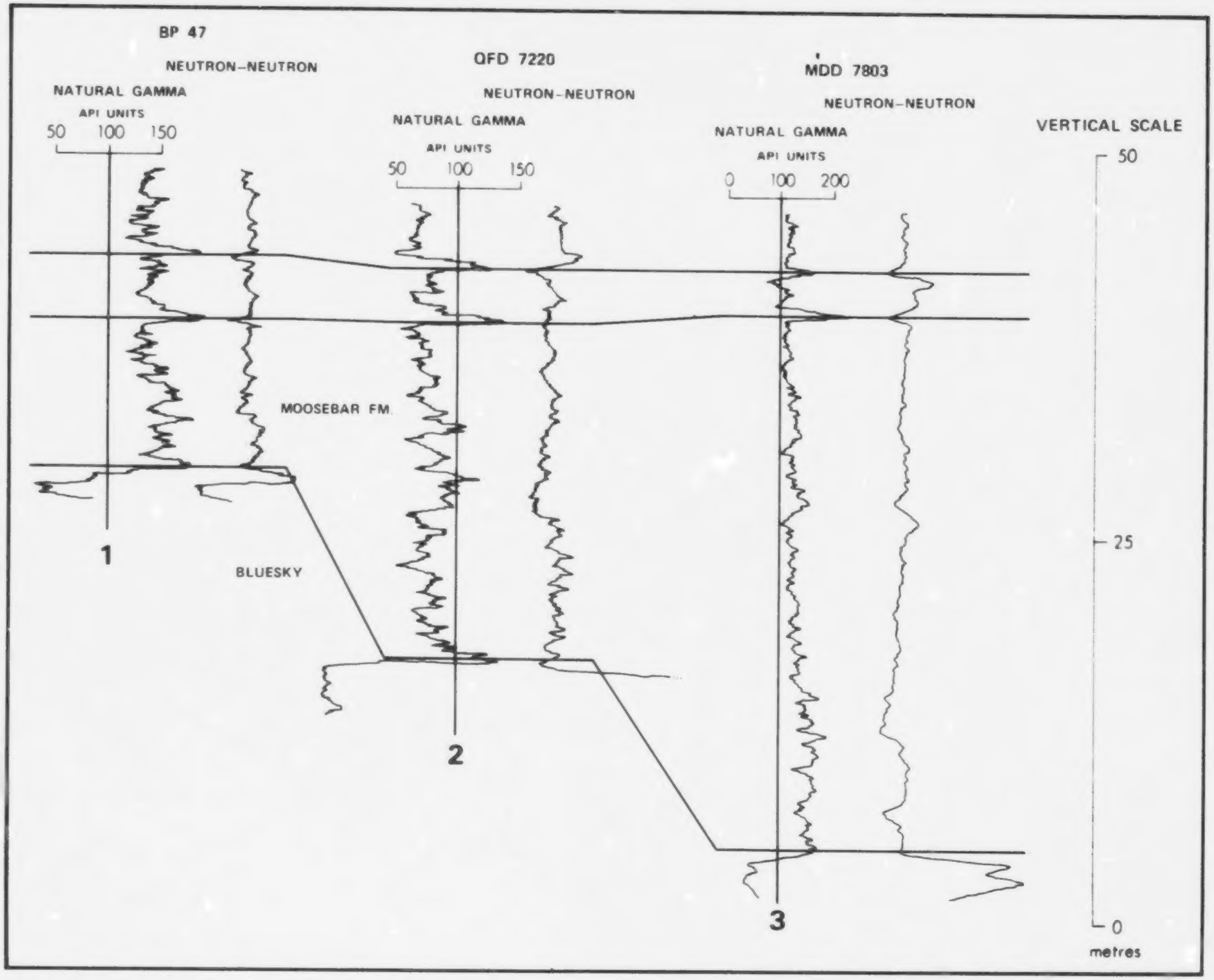


Figure 93. Twin bentonite horizons and the Gething-Moosebar formational contact. See Figure 90 for location.

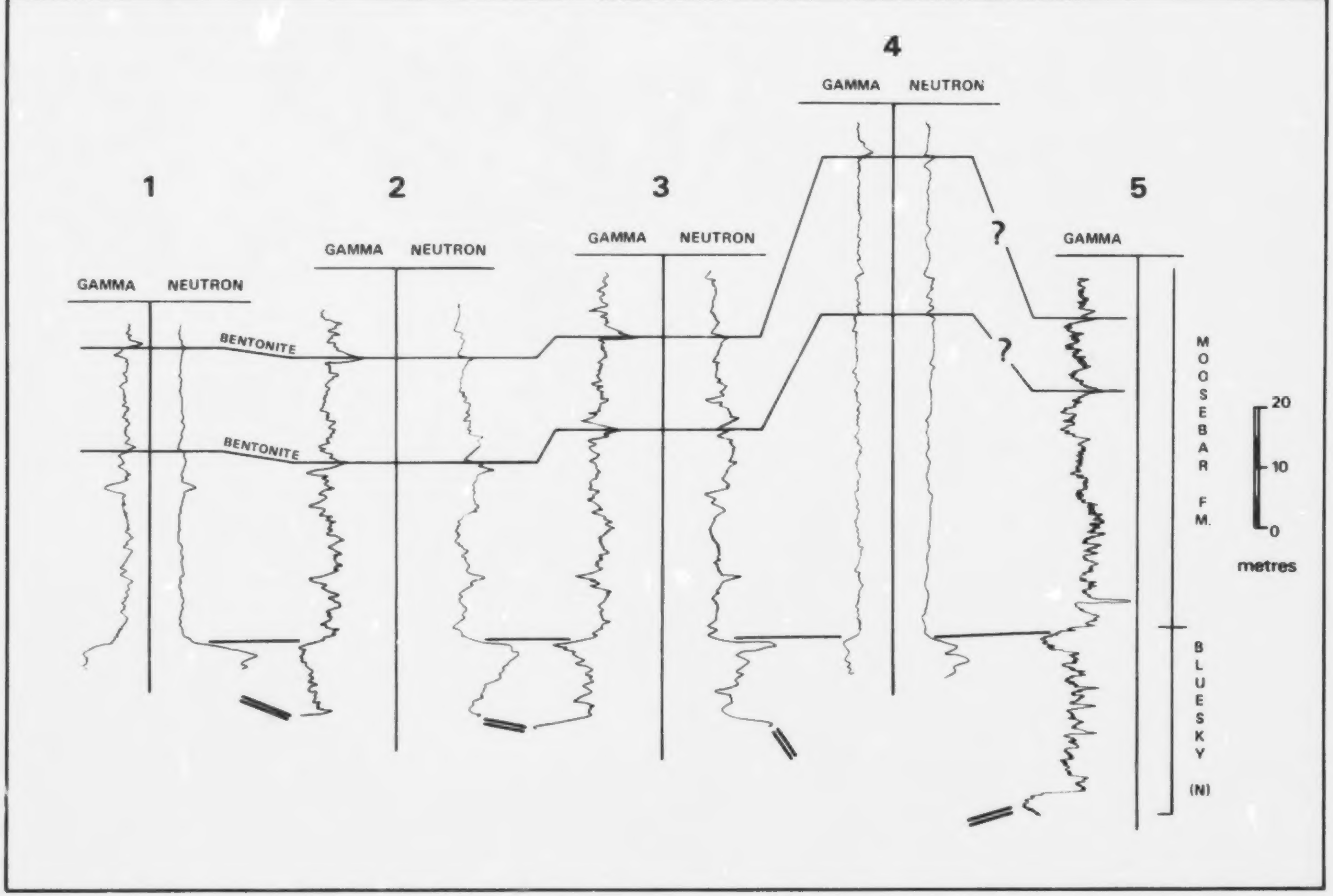


Figure 94. Borehole geophysical traces of the lower Moosebar to Bluesky interval north of the Sukunka River area. Column 4 is exaggerated due to bedding to core angles of 50 degrees. See Figure 90 for location.

TABLE 1
ANALYSES OF 58 TONSTEIN SAMPLES

SAMPLE	FORMATION	SIO2	AL2O3	FE2O3	MGO	CAO	NA2O	K2O	TIO2	MNO	P2O5	Rb	Sr	Zr
R82-1	MOOS	37.72	21.76	4.0	4.15	9.94	.10	.32	.61	.035	.35	<5	160	108
R82-2	MOOS	49.98	27.62	2.31	.99	2.39	.35	1.6	.77	.006	.48	22	264	57
R82-3	MOOS	43.68	35.07	2.91	<.11	1.14	.12	.15	.64	.01	.96	<5	642	105
R82-4	MOOS	21.79	15.69	7.28	7.67	17.41	.1	.1	.46	.051	.23	<5	197	43
R82-5	GETH	44.97	36.64	.05	.15	.12	.14	.3	.88	.004	.02	<5	43	36
R82-6	GETH	45.69	33.0	.12	<.11	<.09	.14	.28	1.05	<.002	.02	<5	46	103
R82-7	MOOS	46.16	32.63	3.62	.65	1.83	.21	.51	.76	.023	.82	<5	270	260
R82-8	GETH	47.17	34.83	1.73	.2	.62	.09	.15	1.17	.013	.45	<5	267	105
R82-9	GETH	52.66	22.7	1.51	1.71	3.78	1.81	.51	.89	.02	.02	<5	188	97
R82-10	GETH	39.04	23.06	3.22	3.95	6.83	.44	1.34	.71	.034	.02	20	104	68
R82-11	MOOS	25.94	19.71	5.84	6.27	14.86	.1	.16	.52	.037	.53	<5	434	185
R82-12	GETH	52.56	18.21	1.46	2.12	4.26	1.14	3.2	.52	.008	.04	32	100	158
R82-13	GETH	48.73	25.79	1.53	1.67	2.68	0.43	5.16	.7	.015	.02	32	62	75
R82-14	GETH	40.34	22.23	2.51	2.81	5.07	0.48	0.88	.69	.03	.02	14	83	120
R82-15	GETH	52.55	26.35	2.36	1.93	0.2	1.37	1.77	.81	.021	.02	22	85	213
R82-16	GETH	52.45	23.54	3.04	2.96	0.58	1.92	1.52	.73	.026	.03	20	111	135
R82-17	GETH	47.87	25.47	2.06	1.52	1.96	0.37	3.83	.72	.02	.02	33	58	95
R82-18	GETH	51.01	26.63	1.16	1.54	3.0	0.83	0.42	1.015	.014	.05	<5	186	260
R82-20	GETH	49.36	33.82	1.11	0.18	0.19	0.02	0.31	1.26	.01	.16	9	330	337
R82-21	GETH	51.15	34.03	0.05	<.11	<.09	0.02	0.06	1.13	.004	.08	<5	300	156
R82-22	GETH	49.86	26.42	0.03	1.48	1.86	1.22	0.98	.79	.014	.02	9	114	184
R82-23	GETH	50.98	34.62	0.15	<.1	0.11	0.01	0.08	1.07	.003	.11	<5	66	168
R82-24	GETH	52.04	21.76	0.26	<.11	0.12	0.03	0.29	1.95	<.002	.07	<5	645	73
R82-25	GETH	44.89	35.27	0.09	0.22	0.15	0.16	0.25	.91	<.002	.02	<5	103	30
R82-26	GETH	53.07	27.78	0.62	0.70	1.86	1.28	0.34	.96	.003	.03	<5	103	232
R82-27	GETH	54.11	27.67	0.8	0.72	0.98	1.45	0.53	.77	.011	.02	<5	213	102
R82-28	GETH	39.49	25.11	4.88	2.61	4.96	1.29	1.18	.8	.34	.07	22	161	144
R82-29	GETH	51.44	24.87	1.6	0.92	1.82	0.549	4.94	.57	.012	.02	55	95	57
R82-30	GETH	53.25	27.38	0.66	0.75	1.18	0.24	1.10	.70	.003	.02	7	167	50
R82-31	GETH	40.47	27.91	12.07	0.99	0.8	0.06	0.74	.75	.097	.29	10	260	54
R82-32	GETH	42.06	33.5	0.23	0.07	0.34	0.05	0.31	.43	<.003	.02	<5	167	26
R82-33	GETH	50.	30.79	3.67	0.09	0.42	0.09	0.44	.7	.017	.24	9	237	45
R82-34	GETH	41.33	23.56	0.22	0.09	0.19	0.06	0.23	.66	<.003	.03	<5	97	25
R82-35	GETH	47.75	34.75	0.27	0.15	0.11	0.48	0.71	1.32	<.003	.03	<5	205	31
R82-36	MOOS	29.63	23.21	4.46	4.98	11.86	0.11	0.21	.56	.024	.79	<5	300	551
R82-37	MOOS	46.34	32.81	2.42	0.53	1.86	0.14	0.72	.59	.011	.65	12	138	406
R82-38	MOOS	20.52	14.31	6.04	8.92	18.42	0.06	0.12	.27	.049	.21	<5	110	197
R82-39	MOOS	37.05	20.84	7.19	3.67	8.64	0.08	0.41	.53	.031	.37	9	150	143
R82-40	MOOS	42.64	18.95	6.4	3.24	7.51	0.15	1.31	.49	.023	.33	21	90	160
R82-41	GETH	53.02	28.92	1.57	0.94	0.59	0.6	0.8	.86	.012	.02	11	177	58
R82-42	GETH	33.86	22.12	4.83	4.36	9.55	0.73	0.51	.87	.051	.33	<5	127	88
DUP-23	*	50.29	35.07	.14	<.06	.26	.02	.11	.92	.004	.12	<5	73	172
DUP-35	*	47.92	34.58	.27	.09	.1	.47	.69	1.31	<.003	.03	<5	222	26
R83-2	GETH	45.82	35.65	.1	.07	.28	.08	.08	.45	<.003	*	10	15	270
R83-3	GETH	43.24	36.48	.15	<.06	.91	.09	.24	.84	<.003	*	10	27	138
R83-5	GETH	39.71	26.71	16.07	.26	.35	.16	.27	.59	.085	*	<10	32	185
R83-6	GETH	36.75	26.19	4.51	2.93	7.83	.06	.38	.6	.031	*	14	320	160
R83-7	GETH	38.44	25.26	16.55	.16	.08	.1	.27	.68	.038	*	15	27	185
R83-8	GETH	48.53	34.1	.74	.16	.32	.38	.77	1.27	.004	*	15	30	312
R83-9	GETH	49.8	33.31	.78	.1	.37	.06	.54	.85	.006	*	13	33	152
R83-10	GETH	51.07	33.41	.12	.07	.13	.06	1.08	1.07	<.003	*	13	22	312
R83-11	GETH	45.77	29.93	8.36	.18	.27	.08	.35	.82	.058	*	15	32	200
R83-13	GETH	49.3	33.72	.26	.1	.45	.04	.37	.68	<.003	*	10	95	200
R83-14	GETH	45.01	31.34	7.54	.2	.28	.04	.34	.85	.4	*	13	21	223
R83-15	GETH	48.23	35.25	.36	.07	.64	.06	.38	.83	.004	*	10	30	138
R83-20	GETH	46.14	32.48	3.58	.2	.79	.06	.28	1.01	.028	*	11	100	152
R83-24	GETH	37.05	24.8	4.75	3.6	6.25	.2	.28	.83	.041	*	15	63	132
R83-25	GETH	51.7	27.91	1.44	.79	1.08	.33	2.64	.62	.007	*	32	100	127
R83-26	GETH	50.18	24.78	2.58	.81	1.37	.64	1.24	.68	.009	*	31	132	177
R83-27	GETH	47.41	30.36	8.52	.24	.26	.08	.35	.83	.061	*	14	45	135

bentonites in the lower Hulcross Formation may provide clues to the source area of the ash and will provide the opportunity to examine the sedimentation rates of intervening strata over a large area. The parallel character of the Gething Formation tonsteins, Bluesky (N), and the bentonites in the lower Moosebar Formation between the Peace and Sukunka Rivers indicates that the whole area was a continuous coastal swamp which was inundated virtually simultaneously over this length during the initial transgressive phases of the Clearwater Sea.

CHEMISTRY

Assessing the potential of chemically correlating the tonsteins was one of the main objectives of the overall project. It was hoped that some means of chemically 'fingerprinting' the various altered ash bands would be found to enable rapid correlation of these horizons when new bands were encountered during exploration. At the end of the field season analytical results became available for a set of 58 samples from the 1982 and 1983 field seasons. These analyses were examined graphically and statistically using a micro-computer. The samples were from the Gething and Moosebar Formations; all were from the Pine River to Brazion Creek region. Preliminary analysis of this data is presented here and a few examples of the correlation potential based on sample chemistry also are given. Analyses for thirteen elements were performed. Si, Al, Fe, Mg, Ca, Na, K, Ti, and Mn were determined using Atomic Absorption Spectroscopy techniques. Samples were prepared by fusion in borate glass crucibles, fluro-borate dissolution, and stabilization of silica. The A.A.S. unit was calibrated using synthetic multi-element standards; the data were reduced on a micro-computer using least squares poly-sensitivity drift monitoring and correction, and a weighted least squares fit calculation for calibration and variance. P, Rb, Sr, and Zr values were determined using X-Ray Fluorescence instrumentation. The lanthinum doped borate glass method was employed using natural standards with line overlap mathematical corrections. All sample preparation and testing were performed by personnel of the Ministry of Energy, Mines and Petroleum Resources Analytical Laboratory. Results of the 58 samples are presented in Table 1. These data were entered into a micro-computer and stored using the Data Handler module of the Cal Data Geological Analysis Package. Most software utilized in the study was contained in the Statistical and Geochemical modules of this package but several programs were written by the author to perform specific procedures. Correlation coefficents between the 13 elements were calculated to examine tendencies of certain element abundances to be mirrored by other elements. Significant positive and negative correlations are highlighted in the correlation coefficent matrix (Fig. 96a). The significances of the matrix values were based on a student's t-test with 11 degrees of freedom at a confidence level of 99 per cent. Positive correlations indicate that as one variable increases or decreases the corresponding element does the same. A negative value means as one element increases or decreases in abundance the corresponding element does the reverse. A

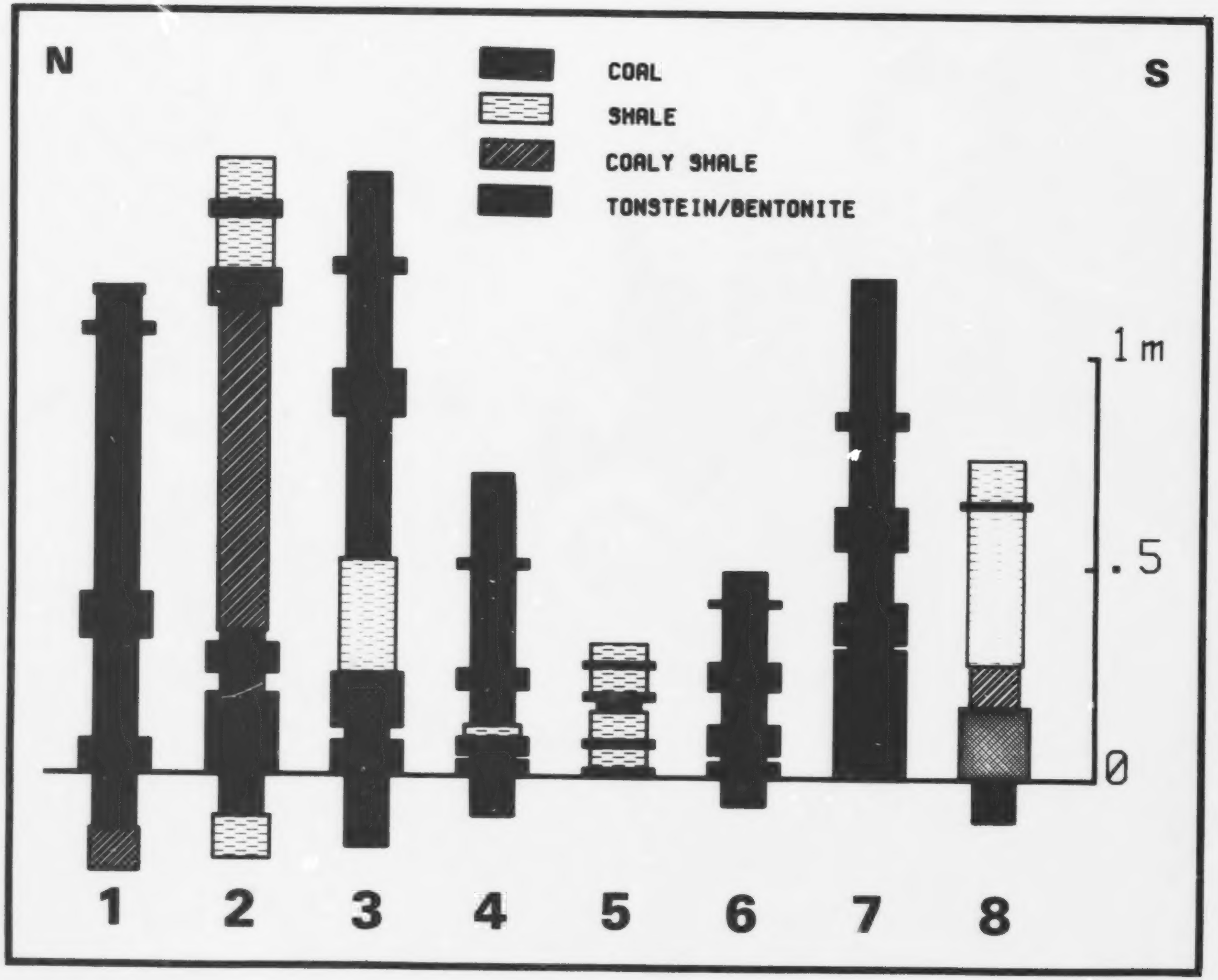

N
S
COAL
SHALE
COALY SHALE
TONSTEIN/BENTONITE
1 m
.5
0
1
2
3
4
5
6
7
8

Figure 95. Detailed sections of the Fisher Creek tonstein zone from widely spaced borehole and outcrop locations. See Figure 90 for location.

dendogram of the matrix was used to graphically illustrate the correlations between elements (Fig. 96b). The strong correlation between Ca and Mg suggests that these elements are related to a common source which would be the secondary carbonates: dolomite, calcite, and magnesite. Mg and Ca have strong negative correlation coefficents with Si and Al, the two most abundant elements. This relationship and the identification of carbonates in many of the samples, by microscopic and XRD methods, suggest that the carbonates were diagenetic. Figure 97 is a ternary plot of $SiO_2/Al_2O_3/CaO$ abundances. The mean SiO_2 to Al_2O_3 ratio is about 1.66:1; the CaO content appears to be completely independent of their concentrations because various concentrations of CaO do not affect the $SiO_2:Al_2O_3$ ratio. Two groups are suggested on the diagram: one contains those samples which were affected by the introduction of carbonate, the other group containing samples which were unaffected by the secondary introduction of carbonate. Samples which showed an increase in carbonate content were found in both the Moosebar and Gething Formations. A plot of TiO_2 versus Zr was used to determine the likely original composition of the ash prior to alteration. The plot follows a procedure similar to Spears and Duff (1984) (Fig. 98). The values were normalized to 15 per cent Al_2O_3. The original ash compositions suggested by this plot were in the andesite to rhyolite range (Winchester and Floyd, 1977). Using these derived original compositions the mean $SiO_2:Al_2O_3$ ratios for andesite and rhyolite are about 4.5:1; average of samples of Mount St. Helens ash had a ratio of 3.5:1. Thus the average tonstein ratio of 1.66:1 indicates that the major chemical affect of alteration was a net loss of silica from the ash bands. The downward migration of silica from bentonites is not uncommon (Grim and Guven, 1978). The strong correlation coefficent between K_2O and Rb is believed to reflect the substitutability of these two elements due to their similar ionic charges and radii.

Correlation of these tonstein samples on the basis of chemistry was attempted by a form of cluster analysis based on similarity coefficients. The similarity coefficient employed had been used successfully to chemically correlate recent volcanic ash horizons (Sarna-Wojcicki, *et al.*, 1984). The coefficient was obtained by calculating the average of the ratios of corresponding elements from the two samples being compared. The denominator was always larger than the numerator in the ratios because the maximum ratio obtainable was 1.0. Eleven elements were used in the calculation, P_2O_5 and Rb were excluded because a significant number of samples were not analysed or were below detection limit for these elements. Element abundances were normalized to 100 per cent in an effort to remove the effect of variable amounts of included organic material which had no expression in the chemical results. Element abundances reported as less than the detection limit arbitrarily were given the value of one half the detection limit. A symmetrical 60 by 60 matrix of similarity coefficents was produced; the two extra samples were laboratory duplicates included to show the sensitivity of the procedure. Information contained in the similarity matrix has been summarized in the form of a dendogram produced using the weighted pair-

SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	MnO	P_2O_5	Rb	Sr	Zr	
1	.49	-.504	-.777	-.831	.343	.296	.463	-.23	-.347	.255	-.096	-.074	**SiO_2**
	1	-.383	-.793	-.736	-.295	-.248	.411	-.13	-.08	-.213	-.103	.063	**Al_2O_3**
		1	.283	.277	-.161	-.129	-.347	.423	.144	.064	-.066	.081	**Fe_2O_3**
			1	.965	.104	.01	-.48	.125	.271	-.035	.103	.071	**MgO**
				1	-.044	-.073	-.478	.107	.358	-.119	.165	.106	**CaO**
					1	.296	0	.069	-.211	.197	-.069	-.054	**Na_2O**
						1	-.183	-.046	-.173	.832	-.192	-.171	**K_2O**
							1	-.087	-.214	-.262	.258	-.054	**TiO_2**
								1	-.041	.109	-.101	.066	**MnO**
									1	-.267	.573	.299	**P_2O_5**
										1	-.321	-.026	**Rb**
											1	-.059	**Sr**
												1	**Zr**

Figure 96a. (a) Correlation coefficient matrix of 13 elements from 58 samples of Moosebar and Gething Formations altered ash bands. Significant positive and negative values are highlighted.

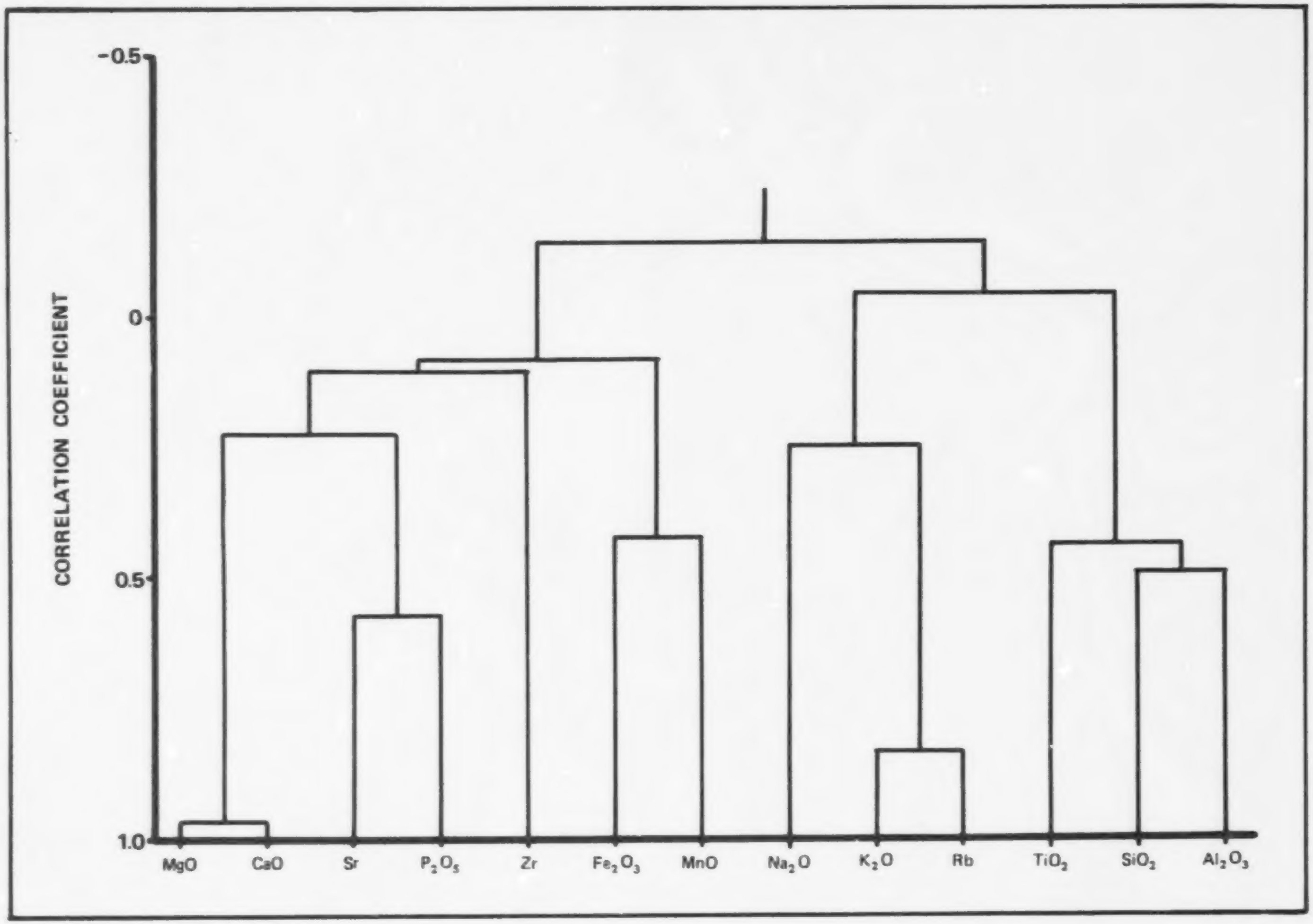


Figure 96b. (b) Dendogram constructed from the correlation coefficient matrix by the weighted pair-group clustering method.

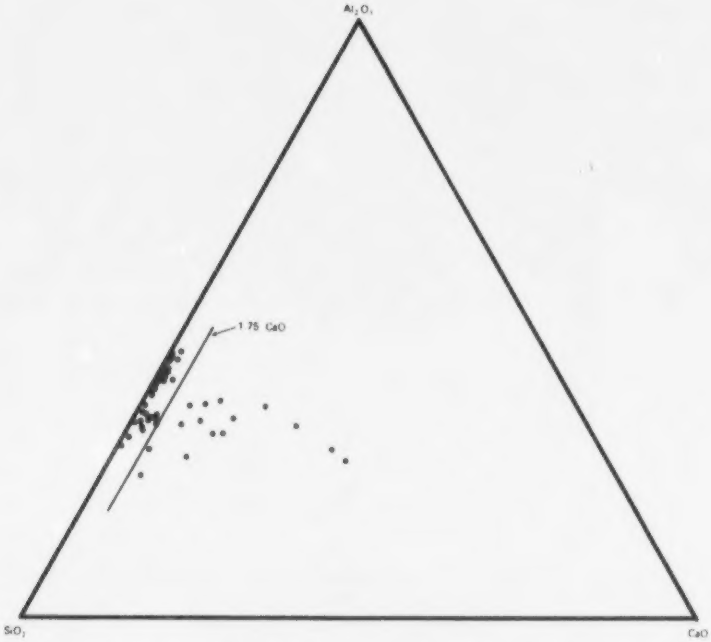


Figure 97. Ternary plot of $SiO_2/Al_2O_3/CaO$ for all 58 samples. Note the consistent SiO_2/Al_2O_3 ratio about 1.66:1 which does not vary as the percentage of CaO changes.

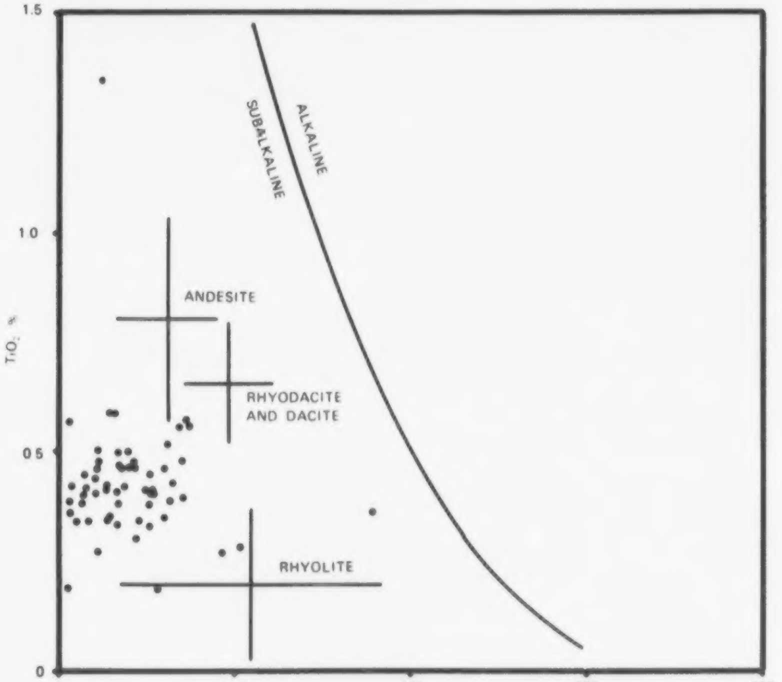


Figure 98. TiO_2 versus Zr plot (Spears and Duff, 1984); for reference, average ratios for andesite, rhyolite, and rhyodacite are indicated (Winchester and Floyd, 1977). Values are normalized to 15 per cent Al_2O_3.

group average clustering technique (Fig. 90). The geological relationships of samples with high similarity coefficients were investigated. The similarity coefficent calculations did not take into account the relative propoitions of various elements in each sample; therefore a difference of 25 per cent to 50 per cent SiO_2 would have the same affect on the similarity coefficient as a 0.02 per cent to 0.04 per cent CaO difference. Thus when interpreting the similarity coefficients care must be used, absolute values are not as important as the relative values for each sample. An example of this problem is demonstrated by the relatively low similarity coefficent between R82-23 and the duplicate of this sample, DUP-23. This difference between identical samples was due to the CaO and Na_2O values (Table 1). The difference between the Na_2O values is well within one standard deviation of the analysis technique and the CaO values are approximately one standard deviation apart. More sophisticated correlation techniques will be performed on this data but even within the limitations of the present method individual horizons could be chemically correlated.

Two boreholes, approximately 2 kilometres apart, drilled through the lower Moosebar Formation intersected similarily positioned bentonite horizons (Fig. 100). In this example three pairs of bentonites were strongly correlated; they had the highest mutual similarities which formed primary linkages on the dendogram. Samples R82-39 and R82-40 had a high similarity coefficent, 0.76; there was no horizon corresponding with R82-40 located in hole 1 which led to the geological interpretation that R82-39 and R82-40 were from the same band which had been structurally repeated in hole 2. It was encouraging that the chemical correlation connected horizons that were geologically acceptable and explained the lack of a corresponding layer to match the R82-40 layer.

Correlation of tonsteins by the method of similarity coefficent matrix examination provided the solution to a confusing series of Gething Formation coal intersections and tonsteins in a borehole (Fig. 101). Similar responses outlining coal seams on the Detailed Sidewall Density trace and chemical correlations of the tonsteins demonstrated which sections were repeats and suggested the locations of the intervening faults. Coal seams A, B, and C are believed to represent an undisturbed section and include four tonsteins. These four tonsteins are believed to be the Fisher Creek Tonstein zone (Fig. 95). Coal intervals A and F are interpreted to be fault duplicates on the basis of the seam density trace and the strong correlations between samples R82-10 and R82-14, and R82-13 and R82-17. Intervals B and C are correlated with intervals D and E on the basis of the density traces and a good correlation between R82-16 and R82-15. Two faults are required to arrive at this configuration of seams and their approximate positions are given on Figure 101. An example of seam correlation between different exposures on the basis of tonsteins is also given on Figure 101. Samples R82-28 and R82-29 correlate with the lower two tonsteins in the undisturbed portion of the borehole section. The uppermost tonstein in the trench, R82-25, correlates with R82-5 and R82-6, the uppermost tonsteins in the two duplicated upper portions of

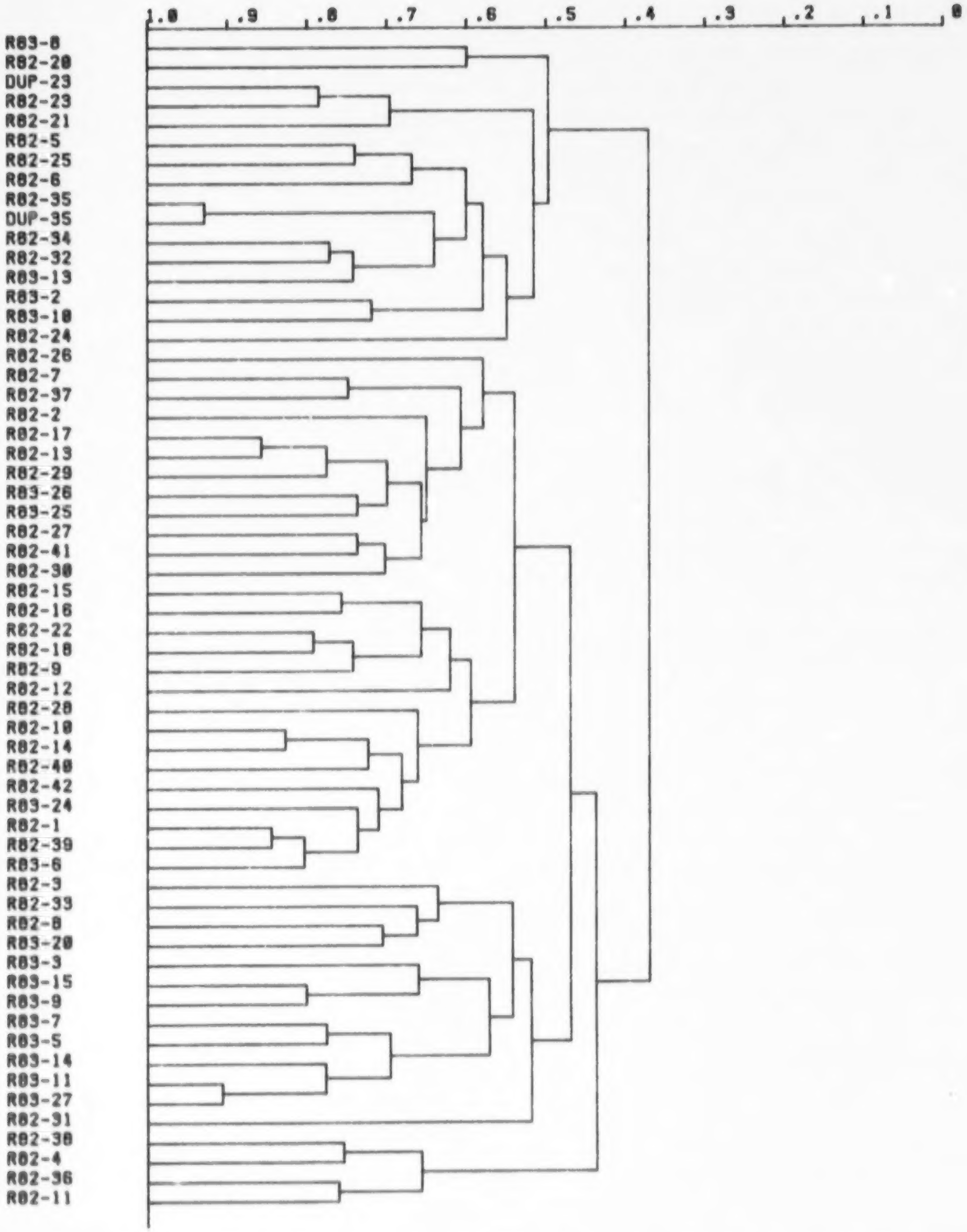


Figure 99. Similarity coefficient dendogram of 60 samples calculated by the weighted pair-group clustering technique. Two duplicate samples (DUP-) are included to illustrate the sensitivity of the method.

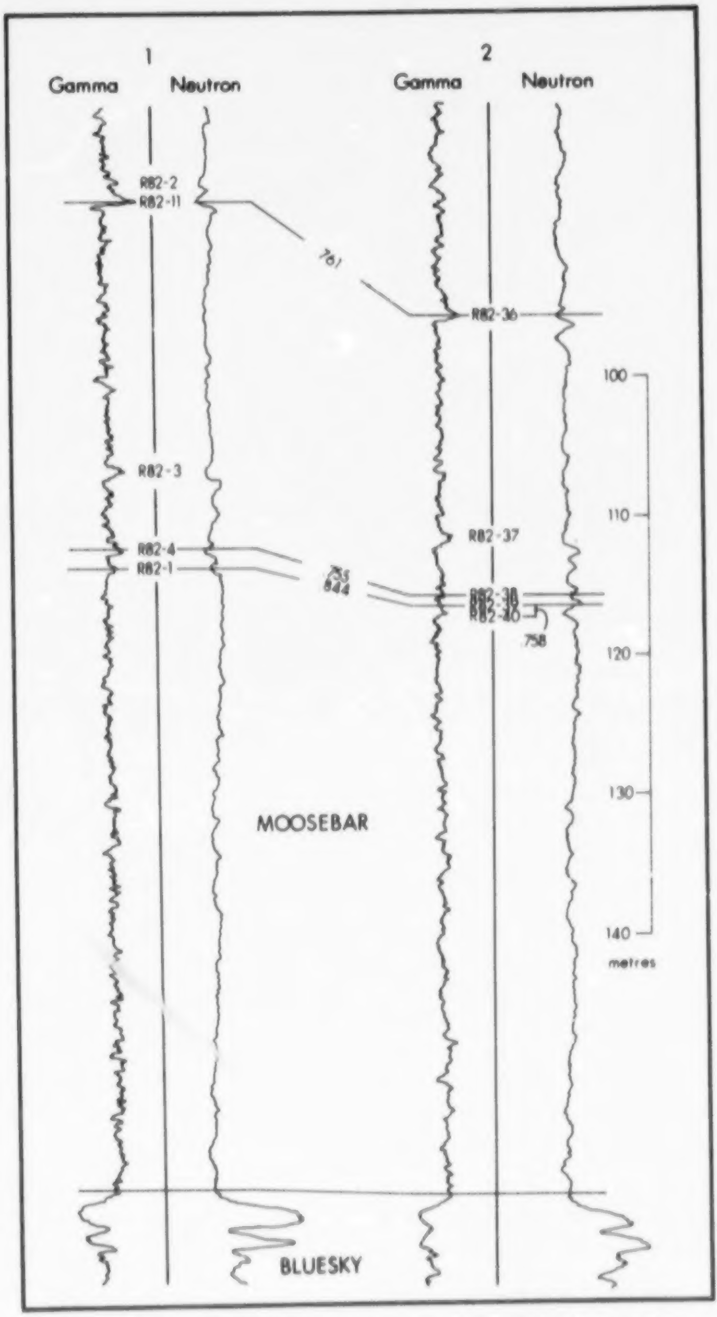


Figure 100. Geophysical logs from two borehole sections of the lower Moosebar and Bluesky sequences. Sample numbers denote the positions of ash bands. Bold correlation lines indicate primary linkages on Figure 99.

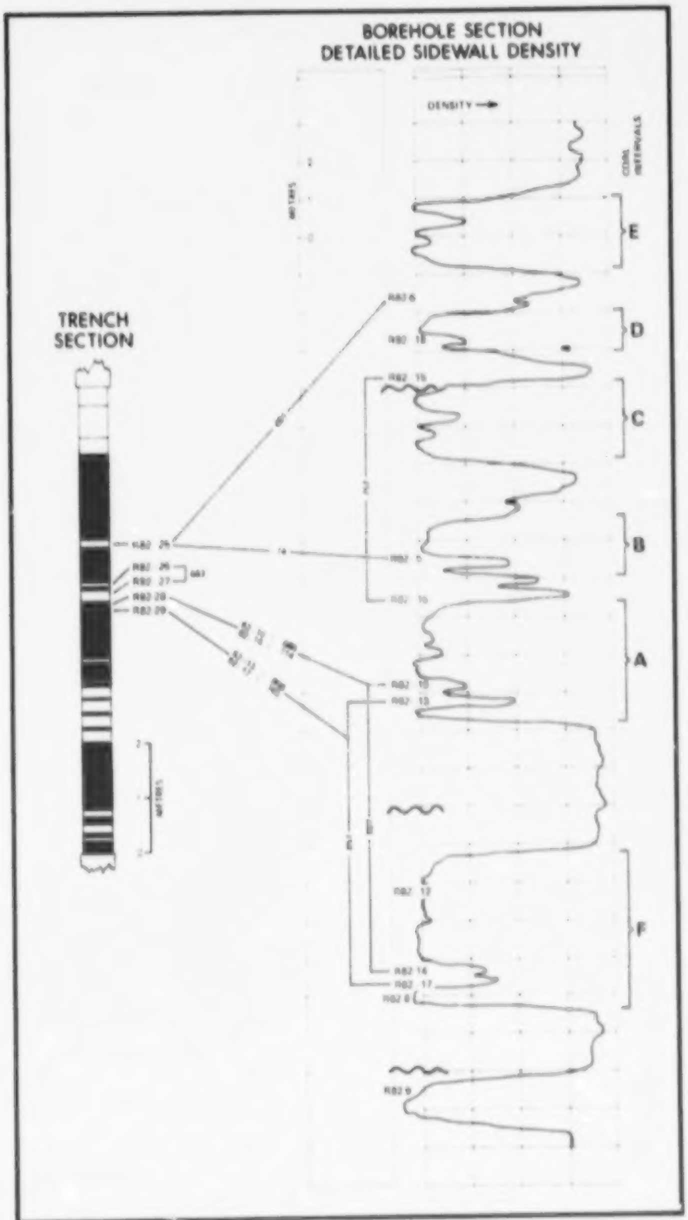


Figure 101. Correlation example from a Gething Formation coal zone. A trench and borehole section are correlated on the basis of similarity coefficients. The fault locations and seam duplications were determined by examination of the geophysical log trace and similarity coefficients. Dashed correlation lines indicate correlations with high similarity coefficients but not the mutually highest coefficients between the two samples.

the coal sequence in the borehole section. Samples R82-26 and R82-27 appear to be one repeated band. The apparent thickness difference between these two sections is due to the bedding-to-core angle in the borehole. This is an excellent illustration that near surface weathering encountered in the trench did not significantly effect the trench samples. The second strongest similarity coefficient (Fig. 99), between samples R83-11 and R83-27, represented correlations between suspected Fisher Creek Tonsteins located approximately 15 kilometres apart. Chemical correlation appears very promising, even using the simplest of statistical techniques. Many of the correlations suggested on the similarity coefficent dendogram are geologically acceptable but have not yet been explored in detail.

MINERALOGICAL

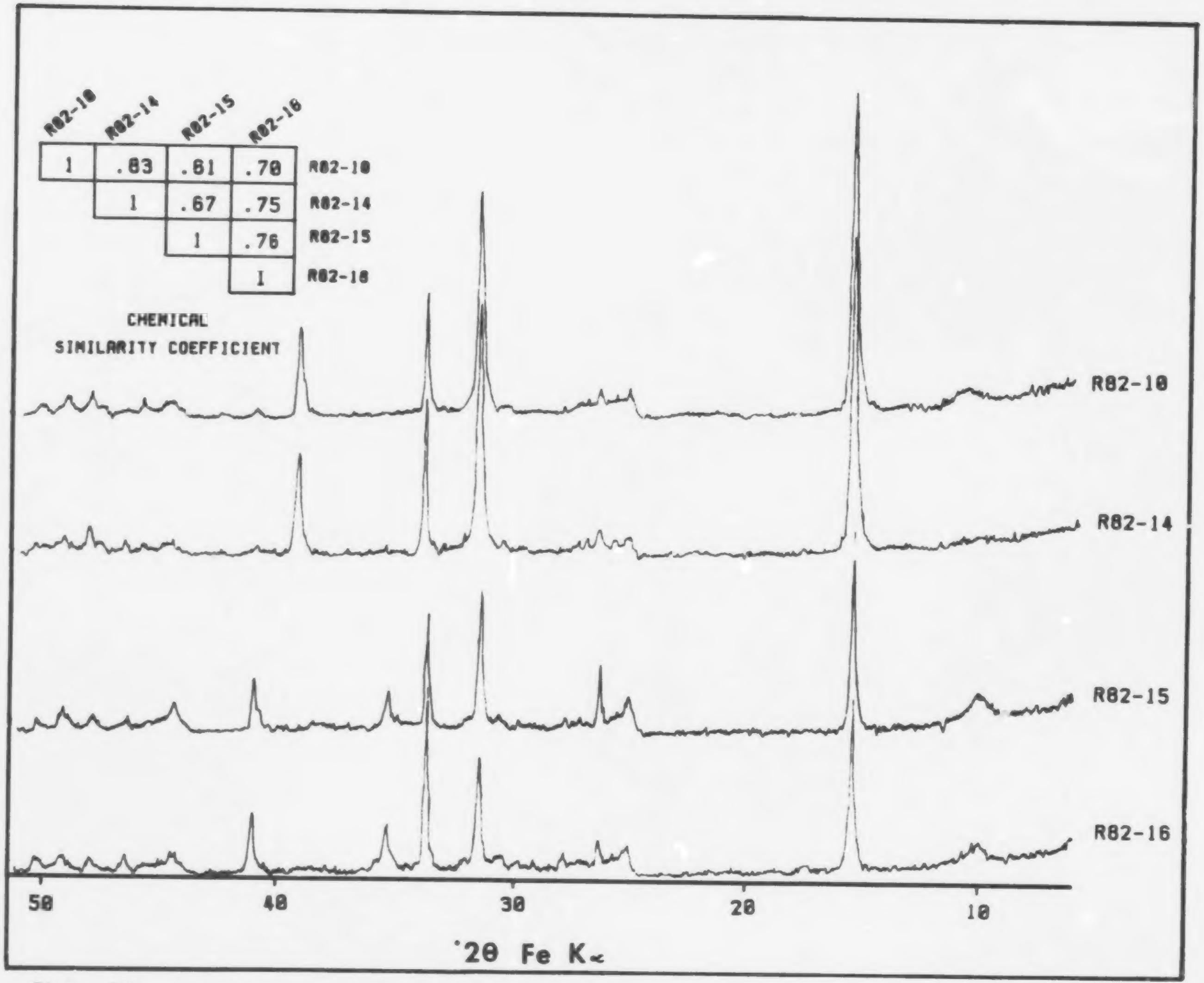
Mineralogical correlation was attempted on the basis of X-Ray diffractograms. Visual examination of the diffractograms of samples which were correlated geologically and chemically showed strong similarities (Fig. 102). In this example two tonsteins located within 2 metres of each other stratigraphically are fault repeated in a borehole (Fig. 101). Diffractograms from the four samples show different mineralogy between the two bands but similar mineralogy between corresponding tonsteins across the fault; strong chemical similarities also exist between these two pairs of samples. It is important to note that even with obviously different mineralogy, similarity coefficients are relatively high between the two bands (R82-16 to R82-14 = 0.748). A combination of chemical and mineralogical correlation may prove to be the most effective approach. This type of correlation is in its initial stages, an automated technique is now under development and should provide relatively fast and cost effective measures of similarity analysis.

CONCLUSION

Work on the Tonstein-Bentonite study during 1984 has: (1) extended the correlation distance of several of the previously described altered ash horizons; (2) initiated age dating of these horizons; (3) shown the ability of chemistry and mineralogy to distinguish specific tonstein-bentonite horizons over limited areas. Future work on this project will be directed to extending correlations of the ash bands, investigating more sophisticated chemical and mineralogical correlation techniques, and documenting stratigraphic relationships relative to these time lines.

ACKNOWLEDGMENTS

The author would like to thank members of the active exploration companies in the area of this study: Gulf Canada Resources Inc., Crows



	R82-10	R82-14	R82-15	R82-16
R82-10	1	.83	.61	.70
R82-14		1	.67	.75
R82-15			1	.76
R82-16				1

CHEMICAL SIMILARITY COEFFICIENT

Figure 102. Example of X-ray diffractograms of four tonsteins illustrated on Figure 101. The chemical similarity coefficients are given in matrix form to provide a comparison between mineralogical and chemical similarities. The XRD measurement rate was °2θ /min and samples were bombarded with FeKα radiation.

Nest Resources Ltd., and Esso Resources Canada Ltd. Their aid in locating occurrences of these ash horizons, access to newly obtained drill core, and stimulating discussion were greatly appreciated.

REFERENCES

Duff, P.McL.D. and Gilchrist, R. D. (1983): Correlation of Lower Cretaceous Coal Measures, Peace River Coalfield, British Columbia, *B.C. Ministry of Energy, Mines & Pet. Res.*, Paper 1981-3, 31 pp.

Grin, R. E. and Guven, N. (1978): Bentonite - Geology, Mineralogy, Properties and Uses, Development in Sedimentology, *Elsevier*, No. 24, 256 pp.

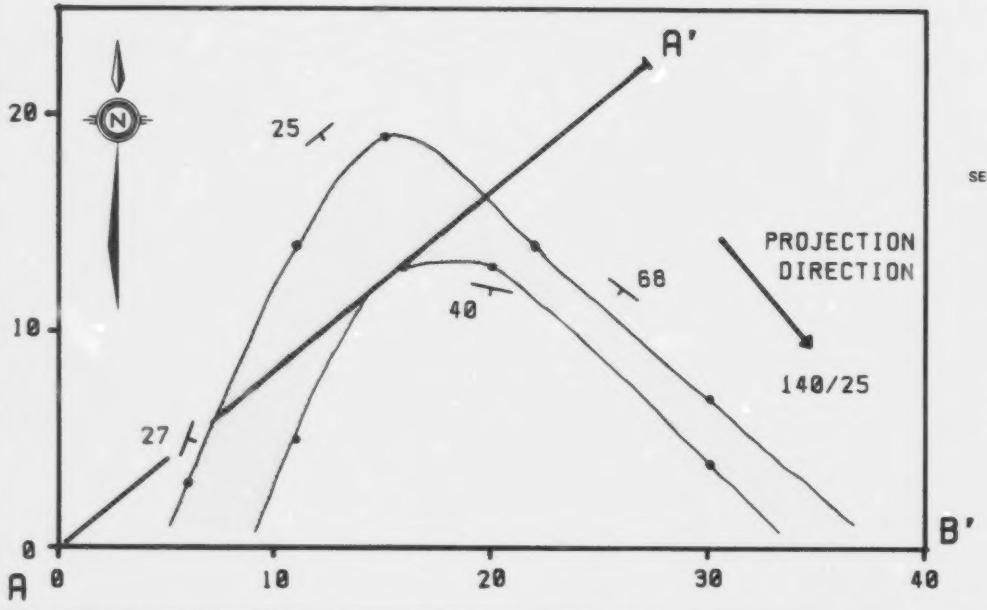
Kilby, W. E. (1984a): The Character of the Bluesky Formation in the Foothills of Northeastern British Columbia (930, P, I), *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1983, Paper 1984-1, pp. 109-112.

..... (1984b): Tonsteins and Bentonites in Northeast British Columbia (930, P, I), *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1983, Paper 1984-1, pp. 95-107.

Sarna-Wojcicki, A. M., Bowman, H. R., Meyer, C. E., Russell, P. C., Woodward, M. J., McCoy, G., Rowe, J. J. Jr., Baedecker, P. A., Asaro, F., and Michael, H. (1984): Chemical Analyses, Correlations, and Ages of Upper Pliocene and Pleistocene Ash Layers of East-Central and Southern California, *U.S. Government Printing Office*, Geological Survey Professional Paper 1293.

Spears, D. A. and Duff, P.McL.D. (1984): Kaolinite and Mixed-layer Illite-smectite in Lower Cretaceous Bentonites from the Peace River Coalfield, British Columbia, *Can. Jour. Earth Sci.*, Vol. 21, pp. 465-476.

Winchester, J. A. and Floyd, P. A. (1977): Geochemical Discrimination of Different Magma Series and their Differentation Products using Immobile Elements, *Chemical Geology*, 20, pp. 325-343.



20
10
0
A
0
10
20
30
40
B'
A'
N
25
27
40
68
PROJECTION
DIRECTION
140/25

INPUT DATA

SEQUENCE	X	Y	Z	DIP DIR.	DIP
1	6	3	0	−1	−1
2	11	14	0	−1	−1
3	15	19	0	−1	−1
4	22	14	0	−1	−1
5	30	7	0	−1	−1
6	11	5	0	−1	−1
7	16	13	0	−1	−1
8	20	13	0	−1	−1
9	30	4	0	−1	−1
10	6	5	0	115	27
11	12	19	0	140	25
12	20	12	0	196	40
13	26	12	0	218	68

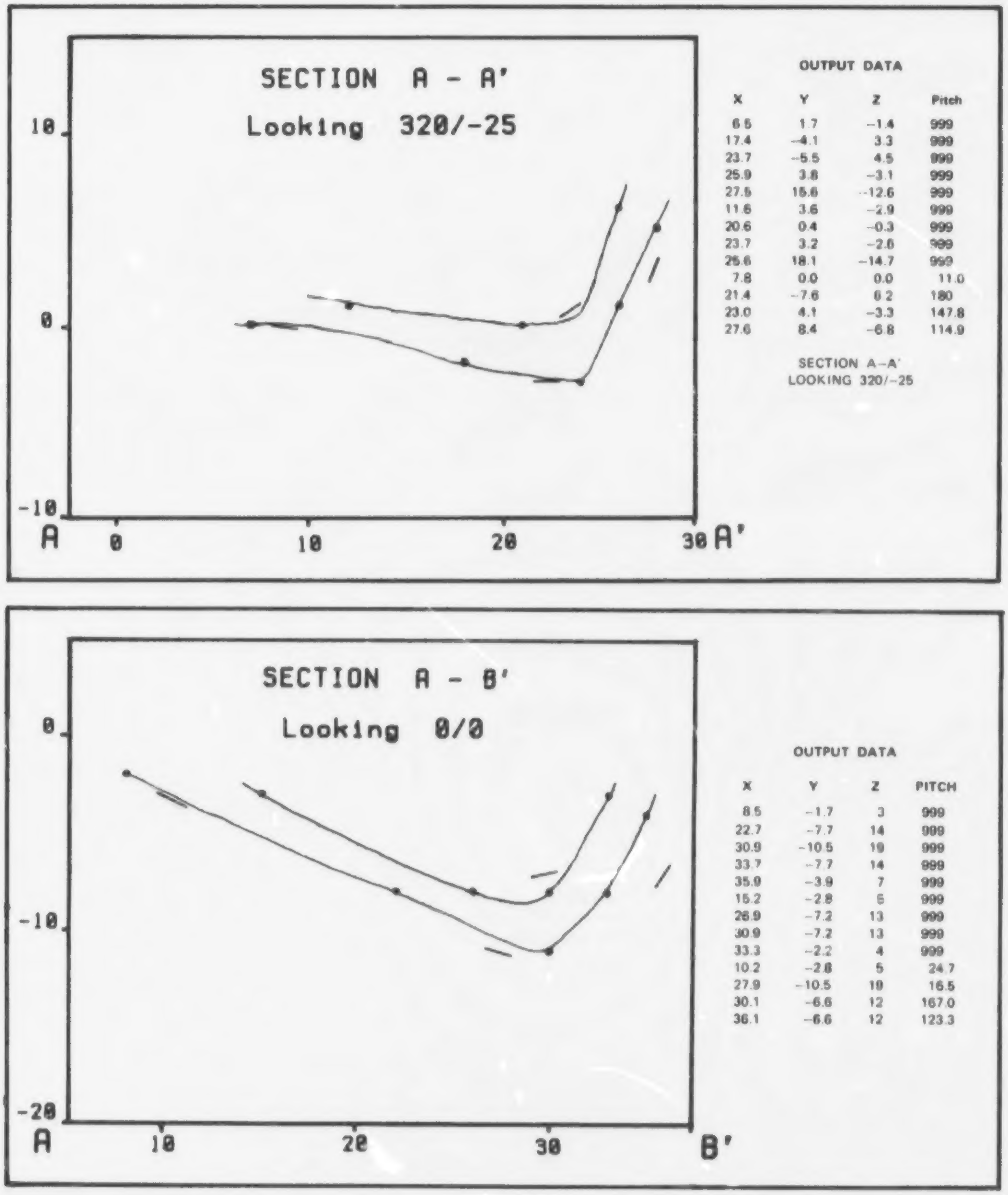
Figure 103. Hypothetical geologic map data. The figure consists of a map view showing a syncline plunging to the southeast and a table with numerical equivalents of the data displayed on the map. Note section lines A-A' and A-B'.

SECTION - A MICRO-COMPUTER PROGRAM
(93, 94)

By W. E. Kilby

Cross-sectional displays of geologic data are one of the mainstays of geological interpretaion, second only to map (plan) displays. Unfortunately, time intensive and error prone manual techniques required to produce all but the simplest form of cross-sections, horizontal projections onto a vertical section, have limited the usefulness of this display form. Horizontal projections are valid when the fold-axes are horizontal, but invalid if the structures have any plunge. Profiles are sections oriented normal to the projection direction; they offer one of the best ways of displaying geologic data to aid interpretation; they display true thickness versus apparent thickness.

```
1 REM************************** SECTION ***************************
2 REM***                       W.E.KILBY                        ***
3 REM*************************************************************
10 PRINT"                    ***SECTION***"
20 PI=3.14159:DR=(2*PI)/360:RD=360/(2*PI)
30 INPUT"PROJECTION DIRECTION, TREND AND PLUNGE";TR,PL
40 INPUT"SECTION VIEWING DIRECTION, TREND AND PLUNGE";VT,VP
50 INPUT"SECTION ORIGIN, X,Y,Z";SX,SY,SZ
60 T1=TR:T2=PL:T3=VT:T4=VP
70 TR=TR*DR:PL=PL*DR:VT=VT*DR:VP=VP*DR:NI=PI/2
80 L1=SIN(VT+NI):M1=COS(VT+NI):N1=0
90 L2=SIN(VT)*COS(VP-NI):M2=COS(VT)*COS(VP-NI):N2=-SIN(VP-NI)
100 L3=SIN(VT)*COS(VP):M3=COS(VT)*COS(VP):N3=-SIN(VP)
110 TR=TR-VT:PL=PL-VP
119 REM INPUT DATA
120 FOR I=1 TO 1000
130 INPUT"ENTER DATA: X,Y,Z,DIP-DIR.,DIP";X,Y,Z,DD,DI
140 IF X=9 AND Y=9 AND Z=9 AND DD=9 AND DI=9 THEN END
150 IF DI>90 THEN DI=180-DI:DD=DD+180
160 X=X-SX:Y=Y-SY:Z=Z-SZ:DD=DD*DR:DI=DI*DR
169 REM CALCULATE SECTION COORDINATES
170 X1=L1*X+M1*Y+N1*Z:Y1=L2*X+M2*Y+N2*Z:Z1=L3*X+M3*Y+N3*Z
180 IF TR=0 AND PL=0 THEN 200
190 X1=X1-TAN(TR)*Z1:ZZ=1/COS(TR)*Z1:Y1=Y1+SIN(PL)*ZZ
199 REM CALCULATE PITCH
200 IF DD<0 AND DI<0 THEN PT=999:GOTO 240
210 DD=DD+PI:DI=NI-DI:L=SIN(DD)*COS(DI):M=COS(DD)*COS(DI):N=-SIN(DI)
220 LL=L*L1+M*M1+N*N1:MM=L*L2+M*M2+N*N2:PT=ATN(LL/MM)*RD
230 IF PT<0 THEN PT=180+PT
239 REM OUTPUT DATA
240 PRINT X1,Y1,Z1,PT
250 NEXT I
260 END
```



OUTPUT DATA

X	Y	Z	Pitch
6.5	1.7	-1.4	999
17.4	-4.1	3.3	999
23.7	-5.5	4.5	999
25.9	3.8	-3.1	999
27.5	15.6	-12.6	999
11.6	3.6	-2.9	999
20.6	0.4	-0.3	999
23.7	3.2	-2.6	999
25.6	18.1	-14.7	999
7.8	0.0	0.0	11.0
21.4	-7.6	6.2	180
23.0	4.1	-3.3	147.8
27.6	8.4	-6.8	114.9

SECTION A-A'
LOOKING 320/-25

OUTPUT DATA

X	Y	Z	PITCH
8.5	-1.7	3	999
22.7	-7.7	14	999
30.9	-10.5	19	999
33.7	-7.7	14	999
35.9	-3.9	7	999
15.2	-2.8	6	999
26.9	-7.2	13	999
30.9	-7.2	13	999
33.3	-2.2	4	999
10.2	-2.8	5	24.7
27.9	-10.5	19	16.5
30.1	-6.6	12	167.0
36.1	-6.6	12	123.3

Figure 104. Cross-section plots of data projected onto two different planes of section. (a) profile A-A', constructed normal to the projection direction (fold-axis), (b) vertical east-west section A-B'. Note distortion of structure in (b) due to oblique angle between structure orientation and section orientation.

The program described here, SECTION (Table 1), calculates the position of a data point on a section of any orientation, after being projected parallel to any desired orientation; and calculates the apparent dip of any orientation data on the plane of the section. The program is written in BASIC with no machine specific features so it can be entered and run on virtually any micro-computer. The user specifies map location and elevation of the map or drill hole data, the orientation and position of the section, and the projection direction. The program returns the resultant section coordinates and the apparent dip of any planar features (Fig. 104 a and b).

SECTION POSITION - It is necessary to position the section relative to the data being investigated. The X, Y, Z (easting, northing, elevation) coordinates specified for the section position become the origin position on the cross-section plot. The specified X and Y map position becomes the zero horizontal position and the Z map coordinate value becomes the zero vertical position on the section plot.

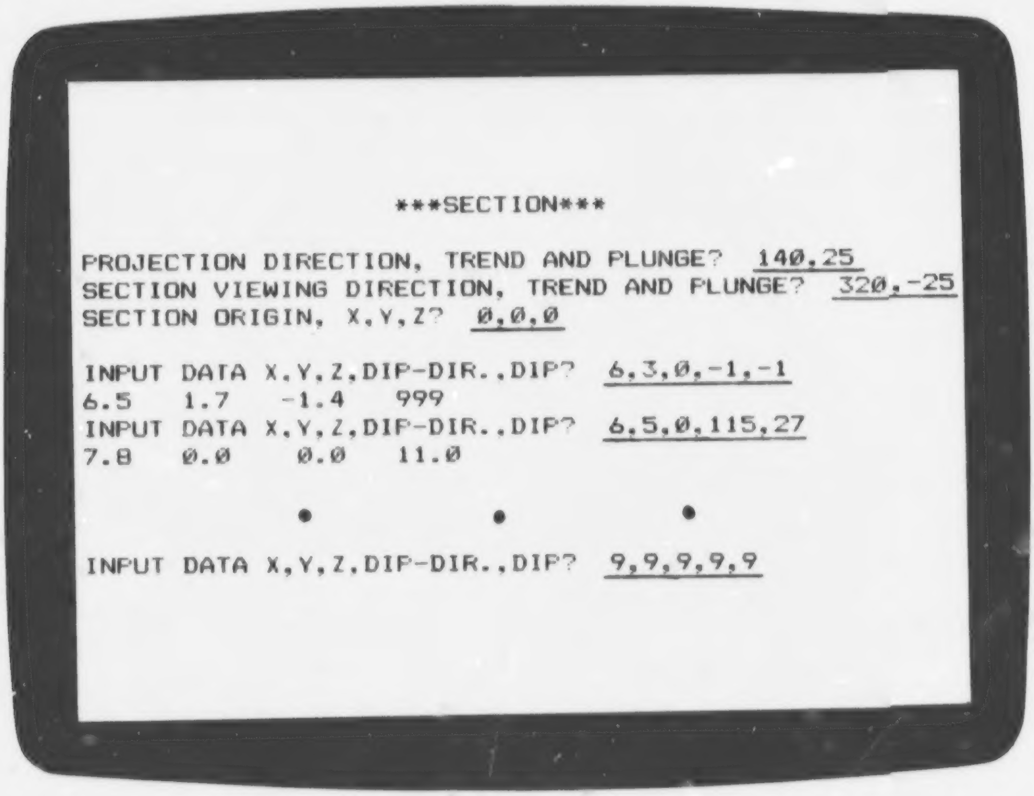
SECTION ORIENTATION - An infinite variety of section orientations can be constructed through any given position. The section orientation is specified by giving the trend and plunge of the direction in which the user wishes to look at the data. For example, a viewing direction of 0/0 (north and horizontal) would result in a vertical section oriented east-west. The viewing direction is perpendicular to the plane of section.

PROJECTION DIRECTION - All data is projected parallel to the given orientation onto the plane of section. A variety of graphical and statistical techniques have been described to aid in the determination of the best-fit fold-axis orientation (Charlesworth, *et al.*, 1976).

INPUT DATA - Positional data is entered as X, Y, Z map coordinates (Fig. 103). These coordinates can be in any map units measured on any grid but the grid must be orthogonal and have the same scale in all directions. Planar orientation data is entered in the form of dip-direction and dip; dip-direction is the clockwise angle measured from grid north. Dip is the vertical downward angle from horizontal to the surface of the structure measured parallel to the dip-direction orientation; dip angles greater than 90 degrees denote overturned bedding. Linear feature orientations should be entered as trend and plunge measurements. Enter a negative (-) value for the dip-direction and dip if no orientation is available for an entry, a pitch value of 999 will be returned to indicate no orientation data was available.

OUTPUT DATA - The position of data on the plane of section is returned as X, Y, Z coordinates, that is the horizontal and vertical distances from the origin in the section, and the normal distance of the point from the plane of section. The apparent dip of orientation data on the section is reported as a clockwise pitch angle.

To illustrate the use of SECTION a hypothetical set of data is employed. Figure 103 contains the raw data and a map representation of this data. In this example the data is projected parallel to the hypothetical fold-axis, 140/25 (trend/plunge). Two cross-sections are constructed; the first, A-A' is a profile, which is oriented normal to the fold-axis (Fig. 104a), the second A-B' is oriented vertical and east-west (Fig. 104b). The results in graphic and numeric form for these two section orientations are given on the figure; this data can be used to check the accuracy of program entry. Figure 105 is a representation of the screen display during program execution.



```
                    ***SECTION***

PROJECTION DIRECTION, TREND AND PLUNGE?  140,25
SECTION VIEWING DIRECTION, TREND AND PLUNGE?  320,-25
SECTION ORIGIN, X,Y,Z?  0,0,0

INPUT DATA X,Y,Z,DIP-DIR.,DIP?  6,3,0,-1,-1
6.5   1.7   -1.4   999
INPUT DATA X,Y,Z,DIP-DIR.,DIP?  6,5,0,115,27
7.8   0.0    0.0   11.0

          •          •          •

INPUT DATA X,Y,Z,DIP-DIR.,DIP?  9,9,9,9,9
```

Figure 105. Example of screen display during program execution. User input is underlined.

The program as given is short, about 1 000 bytes without the REM statements, but extremely powerful. Modifications to the program to allow file handling and plotter output turn this program into a very sophisticated geological tool. The author has used this program in conjunction with larger programs which produce such varied products as isometric net diagrams of grid surfaces (*see* Grieve and Kilby, this volume), borehole deviation diagrams from dip-metre surveys, rotation of map data from one grid system to another, and varied forms of cross-section displays.

REFERENCES

Charlesworth, H.A.K. and Kilby, W. E. (1981): Calculating Thickness from Outcrop and Drill-hole Data, *Cdn. Pet. Geol.*, Bull., Vol. 29, No. 2, pp. 277-292.

Charlesworth, H.A.K., Langenberg, C. W., and Ramsden, J. (1976): Determining Axes, Axial Planes and Sections of Macroscopic Folds Using Computer-based Methods, *Cdn. Jour. Earth Sci.*, Vol. 13, pp. 54-65.

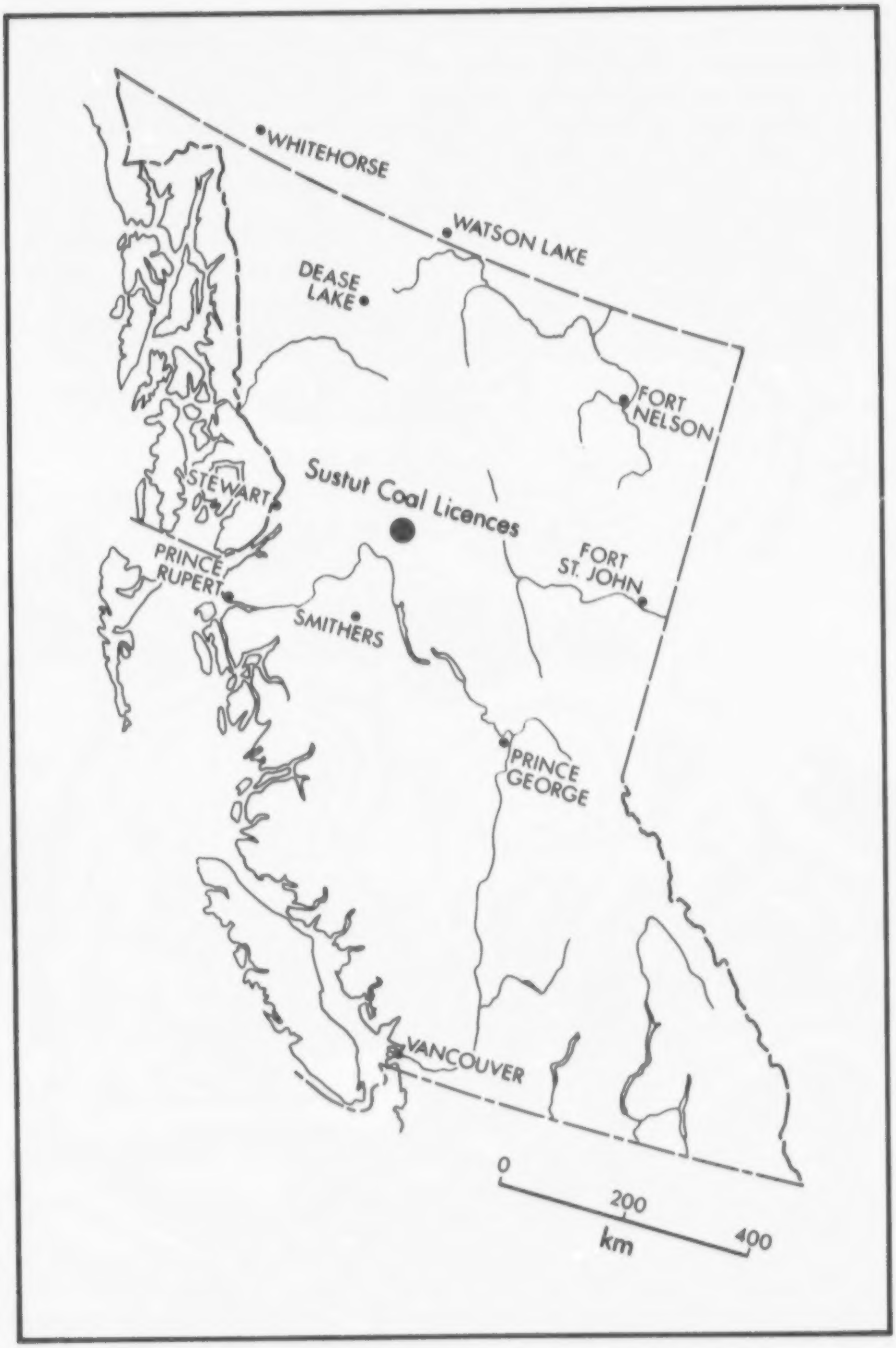

WHITEHORSE
WATSON LAKE
DEASE LAKE
FORT NELSON
STEWART
Sustut Coal Licences
FORT ST. JOHN
PRINCE RUPERT
SMITHERS
PRINCE GEORGE
VANCOUVER
0
200
400
km

Figure 106. Sustut coal licences, property location map.

THE SUSTUT COAL MEASURES
(94D)

By T. G. Schroeter and G. V. White

INTRODUCTION

Recent interest and successful exploration programs in the Telkwa and Klappan coal measures in northwestern British Columbia have attracted other companies to explore for coal elsewhere in the region. The Sustut coal measures represent one such area, which Suncor Inc. Resources Group have explored by diamond drilling during the 1983 (seven holes totalling 1 464.2 metres) and 1984 (10 holes totalling 1 027.8 metres) seasons.

The present investigation, which consisted of three field days and six office days, was carried out to examine the property geology, structural development, depositional environment, age, areal extent, nature of the coal seams, and possible economic significance.

Suncor holds 23 coal licences on 6 624 hectares of land located approximately 170 kilometres north-northeast of Smithers and 10 kilometres northeast of Bear Lake; it is centred at latitutde 56 degrees 20 minutes north and longitude 127 degrees 30 minutes west (Fig. 106). Access to the property is via fixed wing aircraft to a good gravel airstrip adjacent to the B.C. Rail line 4 kilometres north of the northern tip of Bear Lake, then by helicopter to the property, 11 kilometres to the northeast.

The Sustut coal property is underlain primarily by strata of Mesozoic and Paleocene age. Coal-bearing strata occur within both the Jura-Cretaceous Upper Bowser Lake Group and the Paleocene Tango Creek Formation.

PROPERTY GEOLOGY

The geology of the Sustut coal licence area is complex. Pronounced folding and faulting in a southeast-northwest direction, with numerous minor faults orientated in a east-west direction, has greatly affected the stratigraphy making correlation difficult. As well, thick overburden, particularly in the valleys, has presented problems for both drilling and mapping programs within the licence area.

The most important coal-bearing sedimentary unit found on the property consists of marine and non-marine sedimentary rocks with lesser volcanic rocks of the Bowser Lake Group. Tipper and Richards (1976) divided the Bowser Lake Group into the coal-bearing Upper Bowser Lake Formation and the lower, non-coal-bearing Ashman Formation.

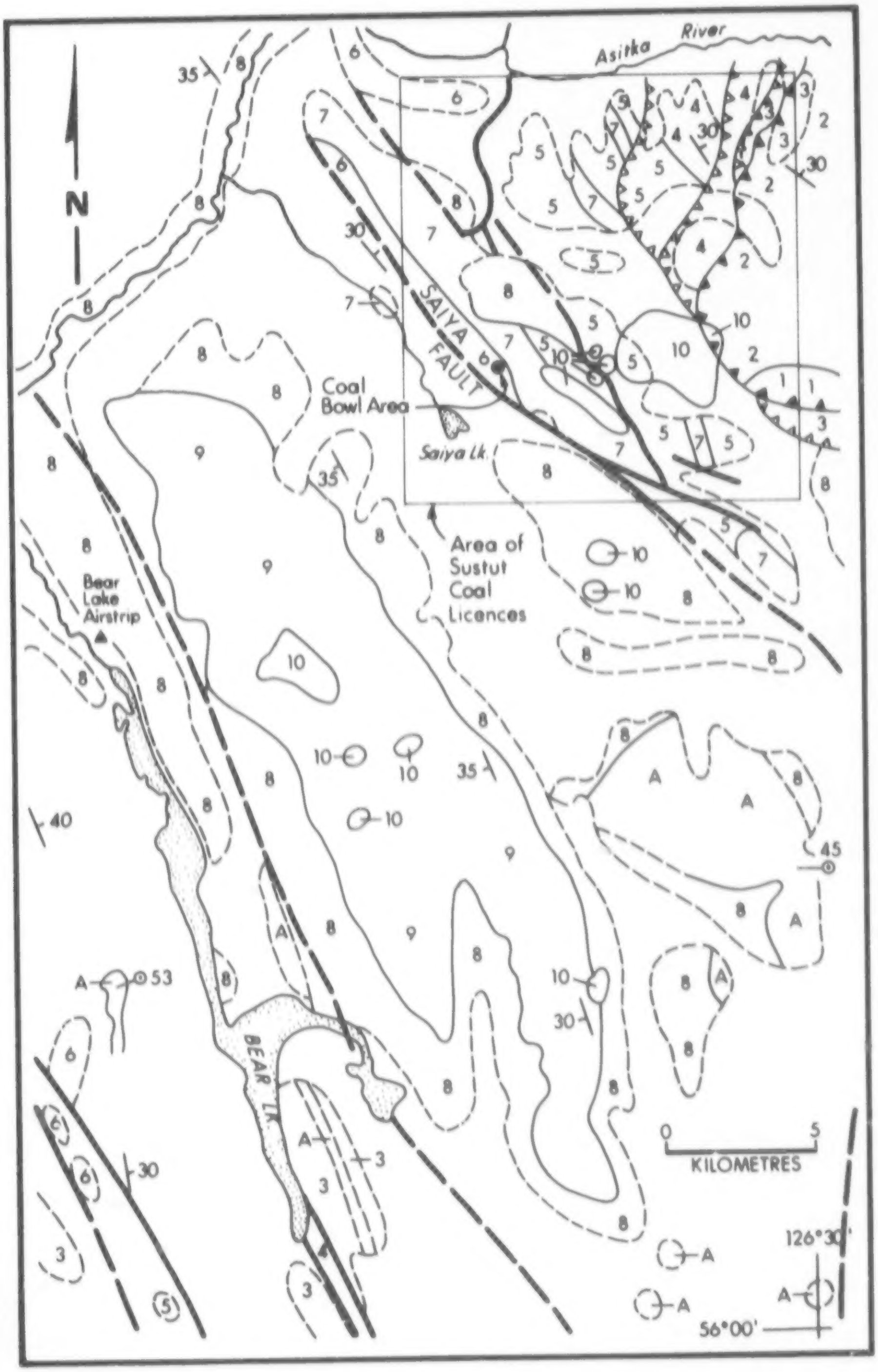

Asitka River
N
SAIYA FAULT
Coal Bowl Area
Saiya Lk.
Area of Sustut Coal Licences
Bear Lake Airstrip
BEAR LK.
0 5 KILOMETRES
126°30'
56°00'
1
2
3
4
5
6
7
8
9
10
A
30
35
40
45
53

Figure 107. Regional geology of the area northeast of Bear Lake (modified after Richards, 1975).

LEGEND

STRATIFIED ROCKS

UPPER TERTIARY AND/OR QUATERNARY

10 BASALT, FLOWS, BRECCIA, PLUGS, AND DYKES

UPPER CRETACEOUS TO EOCENE

SUSTUT GROUP

9 **BROTHERS PEAK FORMATION**: CONGLOMERATE, SANDSTONE, SILTSTONE AND ACID TUFF; MINOR COAL

8 **TANGO CREEK FORMATION**: CONGLOMERATE, SANDSTONE, AND SILTSTONE; MINOR COAL

JURASSIC

MIDDLE AND UPPER JURASSIC

BOWSER LAKE GROUP

UPPER OXFORDIAN

7 VOLCANICS: BASALT AND ANDESITE FLOWS, BRECCIA, TUFF, AND LAHARS

6 SEDIMENTS: SANDSTONE, SILTSTONE, ARGILLITE, AND CONGLOMERATE; MINOR COAL

CALLOVIAN TO LOWER OXFORDIAN

5 **ASHMAN FORMATION**: ARGILLITE AND SILTSTONE; MINOR SANDSTONE AND TUFF

LOWER AND MIDDLE JURASSIC

HAZELTON GROUP

MIDDLE TOARCIAN TO MIDDLE BAJOCIAN

4 **SMITHERS FORMATION**: GREYWACKE, SILTSTONE, SANDSTONE, AND TUFF

SINEMURIAN TO ?LOWER PLIENSBACHIAN

3 **TELKWA FORMATION**: CALCALKALINE BASALT, ANDESITE, DACITE AND RHYOLITE FLOWS, BRECCIA, TUFF AND LAHARS; INTRAVOLCANIC FANGLOMERATE, CONGLOMERATE, SANDSTONE, AND SILTSTONE

▨ POLYMICTIC CONGLOMERATE WITH ASITKA, TAKLA, AND GRANITIC CLASTS

UPPER TRIASSIC

TAKLA GROUP

UPPER KARNIAN TO MIDDLE NORIAN

2 **DEWAR FORMATION**: TUFF, SANDSTONE, AND ARGILLITE; MINOR LIMESTONE AND BRECCIA

PERMIAN

ASITKA GROUP

1 BASALT, RHYOLITE, TUFF, CHERT, ARGILLITE, AND CARBONATE

INTRUSIVE ROCKS

EOCENE

A **KASTBERG INTRUSIONS**: QUARTZ MONZONITE, QUARTZ EYE PORPHYRY AND FELSITE

SYMBOLS

GEOLOGIC BOUNDARY: KNOWN, APPROXIMATE	——— - - - -
FAULT: KNOWN, APPROXIMATE	━━━ ━ ━
HIGH ANGLE REVERSE FAULT KNOWN, APPROXIMATE	▲▲▲▲
THRUST FAULT: KNOWN, APPROXIMATE	▲▲▲ ▲
BEDDING, UPRIGHT	┴
K/Ar AGE DETERMINATIONS (Ma)	⊙

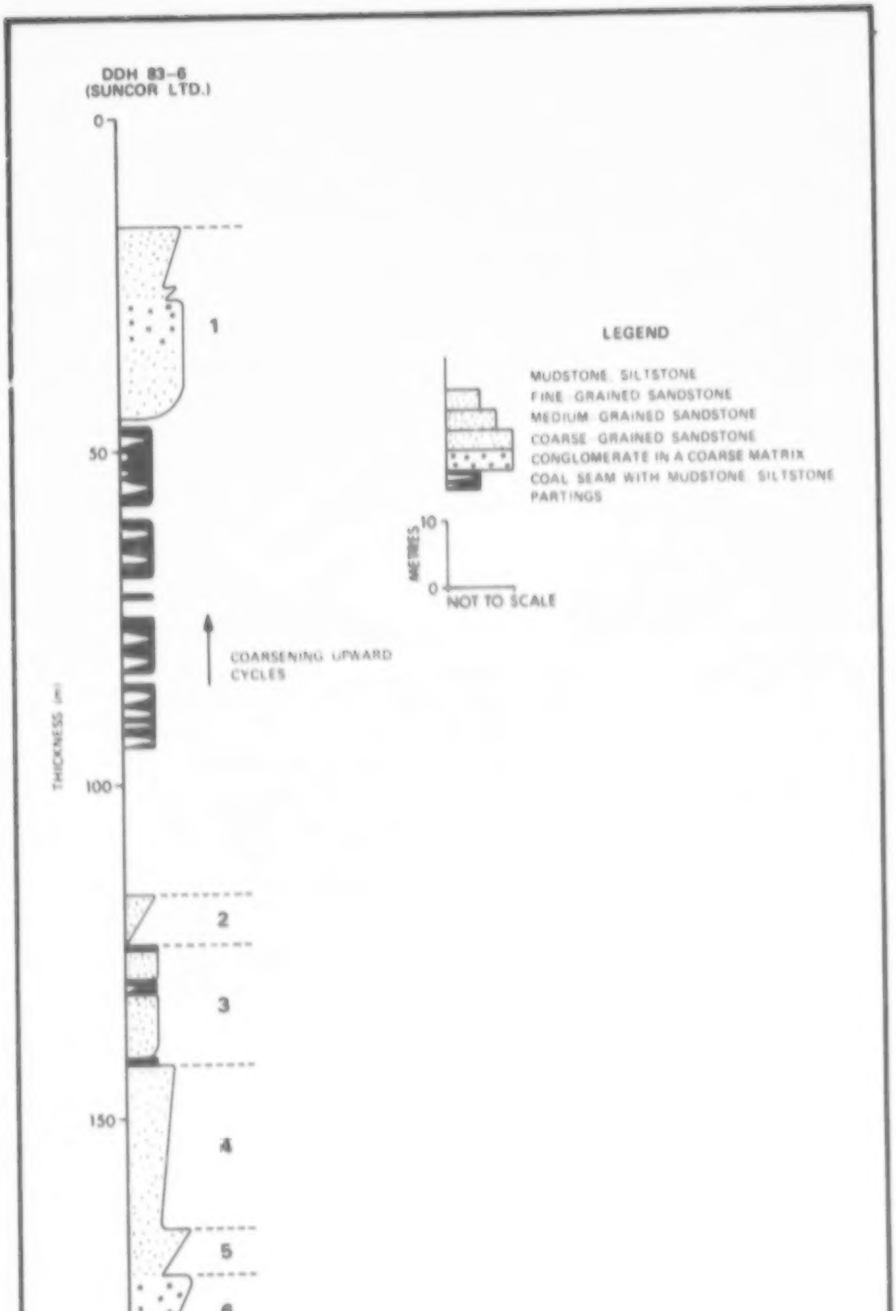

DDH 83-6
(SUNCOR LTD.)
0
50
100
150
185
THICKNESS (m)
1
2
3
4
5
6
COARSENING UPWARD CYCLES
LEGEND
MUDSTONE SILTSTONE
FINE GRAINED SANDSTONE
MEDIUM GRAINED SANDSTONE
COARSE GRAINED SANDSTONE
CONGLOMERATE IN A COARSE MATRIX
COAL SEAM WITH MUDSTONE SILTSTONE PARTINGS
METRES
10
0
NOT TO SCALE

Figure 108. Stratigraphic section of sedimentary rocks of the Upper Bowser Lake Formation.

Based on diamond-drill core and geophysical log examination, Upper Bowser Lake rocks within the licence area consist of sandstones, siltstones, mudstones, shales, and coals. The sandstones are fine to coarse grained, light to medium grey in colour, exhibit crossbedding in places, and generally are well sorted. The siltstones are light brown in colour and appear to be part of a fining upward sequence. They do not form thick units (for example, 2 to 3 metres) and are bioturbated. The carbonaceous mudstones and shales are dark grey to black in colour and closely associated with the coal horizons; they represent periods of low energy with low levels of input of fine sediments.

Coals in the Upper Bowser Lake Formation within the licence area are of high to medium volatile bituminous rank. Company tests also suggest that coals of sub-bituminous and low volatile bituminous rank occur.

Major outcrops of coal are situated in an area that company personnel call the 'Coal Bowl' (Fig. 107). At this location, considerable trenching has revealed seams up to 9 metres in thickness; however, they are steeply dipping (up to 90 degrees) and seam correlation is difficult.

From examination of drill core and geophysical logs it appears that a general coarsening upward sequence characterizes the Upper Bowser Lake Group (Fig. 108). The sediments were probably deposited in a deltaic environment and the coal seams could have substantial lateral extent. However, intense faulting and folding within the licence area has greatly interrupted the continuity of the sequence.

The non-coal-bearing Ashman Formation of the Bowser Lake Group lies conformably below the coal-bearing Upper Bowser Lake Formation. This formation crops out within the licence area and is not easily distinguished from the Upper Bowser Lake Formation. Company geologists have separated the Upper Bowser Lake from the Ashman Formation by the presence of concretions in the Ashman. These concretions are light brown to rusty brown in colour and range in size from 1 to 20 centimetres. No concretions have been recognized within Upper Bowser Lake sedimentary rocks.

A second coal-bearing stratigraphic unit occurs in the Sustut Group, which lies unconformably over the Bowser Lake Group and crops out within the licence area. Eisbacher (1974) divided this group into the Upper Brothers Peak Formation and the coal-bearing Tango Creek Formation.

These sediments were recognized by company geologists, but because of limited time and transportation, were not examined by the writers. Suncor geologists report that coal is present in the upper portion of the Tango Creek Formation but that correlation is made difficult and seam continuity is disrupted by extensive folding and faulting.

CONCLUSIONS

The intense folding and faulting and thick overburden in valley bottoms inhibits coal exploration within the Sustut coal licence area. Nonetheless, substantial Middle to Late Jurassic coal seams with low to high volatile bituminous ranks have been identified. Further mapping and drilling are needed to assess the nature and extent of the Sustut coal measures.

ACKNOWLEDGMENTS

The writers would like to thank Suncor Resources Incorporated of Calgary, in particular, project geologist John Fisher and staff, for their generous support and willing cooperation.

REFERENCES

Eisbacher, G. H. (1974): Sedimentary History and Tectonic Evolution of the Sustut and Sifton Basins, North-central British Columbia, *Geol. Surv., Canada*, Paper 73-31.

Richards, T. (1975): McConnell Creek Map-area, *Geol. Surv., Canada*, Open File 342.

Tipper, H. W. and Richards, T. A. (1976): Jurassic Stratigraphy and History of North-central British Columbia, *Geol. Surv., Canada*, Bull. 270.

TOODOGGONE RIVER AREA
(94E)

By T. G. Schroeter

INTRODUCTION

The Toodoggone River area, which lies approximately 300 kilometres north of Smithers, hosts several significant precious metal deposits. Access into the area continued to be aircraft only, mainly from Smithers.

The writer spent a total of six days visiting key properties with the aim of examining the mineral deposit settings, mineralogy, and alteration patterns to extend earlier investigations in areas where diamond drilling was in progress. The data will be incorporated into a preliminary map of the Toodoggone area at a scale of 1:50 000 as part of a joint project with Andre Panteleyev and Larry Diakow, and should be available in January 1985.

For more detailed descriptions of the area the reader is referred to articles in previous publications of Geological Fieldwork.

WORK DONE

Work carried out by companies in the Toodoggone River area in 1984 included the following:

(1) SEREM INC.
Lawyers (Fig. 109, No. 37; Mineral Inventory 94E-66, 67, 74); 7 010.4 metres (23,000 feet) of diamond drilling in 45 holes.

An extensive development program by SEREM Inc. consisting of surface diamond drilling on the Amethyst Gold Breccia Zone (AGB, Mineral Inventory 94E-66), Cliff Creek Breccia Zone (Mineral Inventory 94E-67), Duke's Ridge Zone (Mineral Inventory 94E-74), and underground diamond drilling on the Amethyst Gold Breccia Zone during the summer of 1984, nearly doubled geological reserves on the Lawyers property; conservatively, reserves now exceed 1 million tons, grading approximately 7.27 grams per tonne (0.211 ounce per ton) gold and 254.2 grams per tonne (7.11 ounces per ton) silver. Company officials estimate that, to date, 20 per cent of known surface structures on the Lawyers property have been tested.

On the AGB Zone, with previously published reserves of 639 813 tonnes grading 7.27 grams per tonne gold and 254.2 grams per tonne silver, 13 underground holes were drilled on the West Zone confirming its existence in the hangingwall stratigraphy.

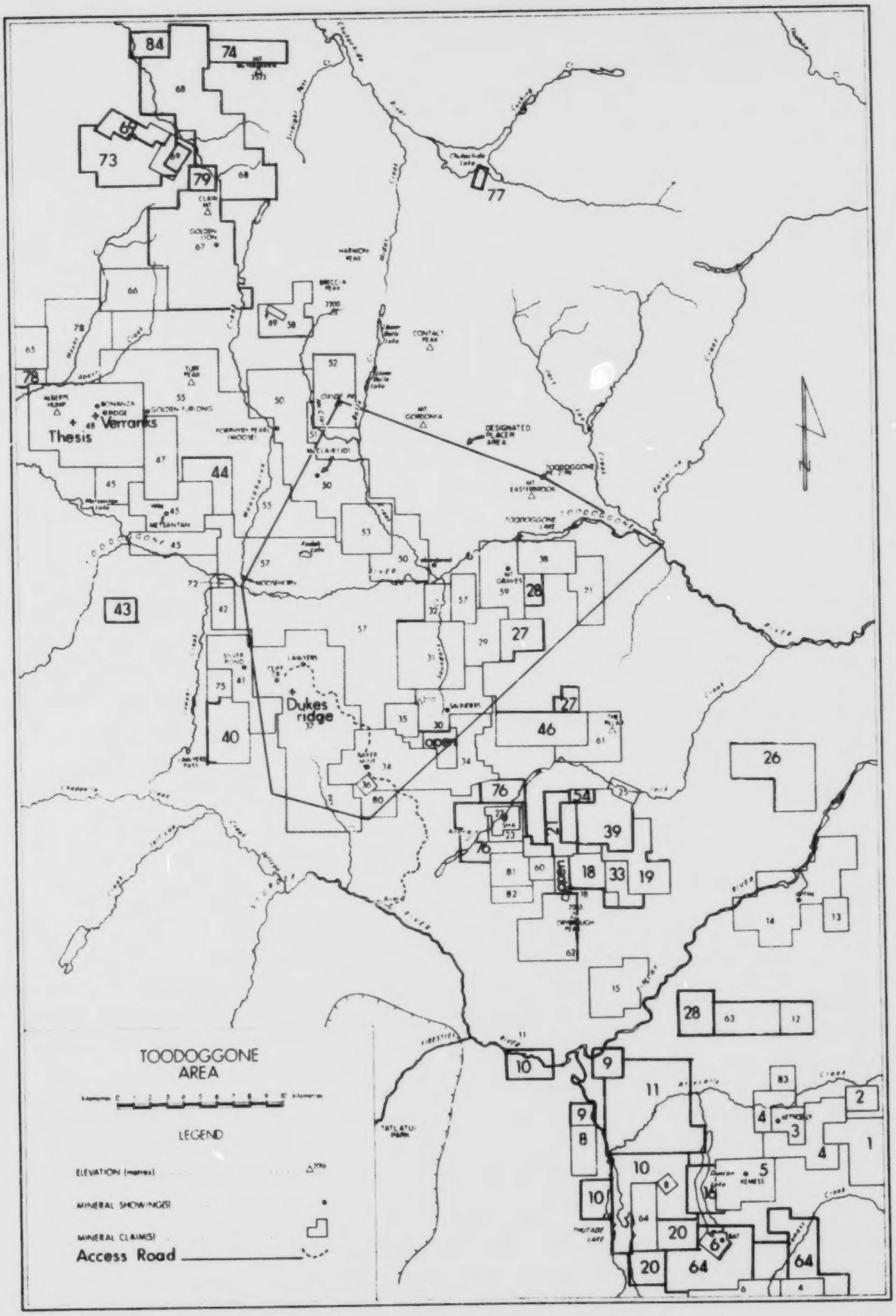

TOODOGGONE
AREA
kilometres 0 1 2 3 4 5 6 7 8 9 10 kilometres
LEGEND
ELEVATION (metres)
MINERAL SHOWING(S)
MINERAL CLAIM(S)
Access Road
Thesis
Verrenks
Dukes ridge
open
TOODOGGONE
TATLATUI PARK

Figure 38. Toodoggone map-area.

Figure 109. Mineral properties, Toodoggone River area.

NO.	CLAIM NAME	MDI 94E	OPERATOR
1	MESS 1-4	70	SEREM
2	AUDREY 1, 2	...	Inca Res.
3	AUDREY EAST, AUDREY WEST	22	Inca Res.
4	KEM 1-9	...	Inca Res.
5	NEW KEMESS 1, 2	21	Kennco
6	RAT	25	Cominco
7	CROWN–GRANTED CLAIMS	12, 13, 14	Cominco
8	FIRESTEEL	2	SEREM
9	FINA 1, 2	...	Asitka Res.
10	LAKE 1-5	...	Pacific Ridge Res.
11	ARK 1-7	...	Ark Energy Corp.
12	RICH	...	Golden Rule Res.
13	MEX	57	Cominco
14	FIN 1-9	16	B. Pearson
15	GRACE 1-5	47, 48, 49	D. MacQuarrie
16	DUNCAN 1-4	...	Gunsteel Res. Corp.
17	RN	3, 4, 5	Winderra Mines
18	GOTCH 1, 2	...	SEREM
19	JOCK 1-5	8	Golden Rule Res.
20	TUT 1, 2	...	Univex Mining Corp.
21	JOCK 1-5	8, 39	SEREM
22	SHAS	50	Newmont
23	SILVER REEF	...	C. Kowall
24	DU	...	A. Smallwood
25	BRENDA 1-8	...	J. Weishaupt
26	NUB MTN.	88	SEREM
27	ARGUS 1-4, ARG 1	28, 29, 42	SEREM
28	AURO 1	...	Aurofina Res. Corp.
29	GWP 200	7	Great Western Pet.
30	GOLDEN NEIGHBOUR 1-4, JOLLY ROGERS, CAMP, CAMP FR.	37	Lacana
31	SAUNDERS	40	Golden Rule Res.
32	GWP 43	...	Great Western Pet.
33	GOLDEN RING	...	Newmont
34	CHAPPELLE	26	DuPont Explor.
35	PEL	...	DuPont Explor.
36	CROWN–GRANTED CLAIMS	27	O. McDonald
37	NEW LAWYERS 1-4, LAW 1-3, BREEZE, ROAD I-III, PERRY 1, 2, MASION 1, 2, GTW 1-3, plus fractions	66, 67, 74	SEREM
38	DUKE 1, 2	...	SEREM
39	JAN 1-4	...	D. Park
40	SILVER CLOUD 1, 2	...	C. Kowall
41	SILVER POND, SILVER CREEK, SILVER PEAK, SILVER GRIZZLY	69	St. Joe Canada
42	KODAH	17	SEREM
43	GOLDEN STRANGER	...	Western Horizons
44	PANT 1-3	...	Kidd Creek Mines
45	METSANTAN 1-9	65	Lacana
46	GOLDSTREAM 1, 2	...	C. Kowall
47	METS 1, 2	...	Golden Rule Res.
48	AL 1-8	78, 79, 85	Kidd Creek Mines
49	HAR	53	Kennco
50	SCREE 1 [illegible] OSE 1-3, JM, JD, J[illegible] cCLAIR 1-5, plus fr[illegible]	31, 32, 65	Kidd Creek Mines
51	GAS 1, 2	...	Kidd Creek Mines
52	KIDVIEW, AMETHYST VALLEY	...	C. Kowall
53	BELLE 1, 2	...	Golden Rule Res.
54	MAY 1-3	...	P. Weishaupt
55	BERT, ERNIE, WINKLE, BULL, CHUTE, SURPRISE, GEROME, OSCAR FR., WANKLE FR., ANTOINE LOUIS, TOUR, STURDEE, BIG BIRD, KADAH, SHODEE, RJ FR., JP FR.	80	Kidd Creek Mines
56	SNAFU	...	Great Western Pet.
57	GWP 1-43, DOUG'S BEAR	...	Great Western Pet.
58	GORDON DAVIES 1, 2	53	Lacana
59	GRAVES 1-7	87	Great Western Pet.
60	DAWN	...	Newmont
61	HERCULES, ATLAS	24	SEREM
62	STAR, ACA, PULL, SUN	58	SEREM
63	WRICH	82	SEREM
64	RON 1-11	...	Pacific Ridge Res.
65	ADOO 1, 2	...	Newmont
66	HUMP 1, 2	...	Newmont
67	GOLDEN LION 1-11	77	Newmont
68	LYNX 1-8	...	Newmont
69	CLAW	46	UMEX
70	KRAB	...	Kidd Creek Mines
71	SUN 1, 2	...	Newmont
72	KODAH 2	68	SEREM
73	COPPER KING 1-6, NAMERA IV	...	Western Horizons
74	McNAMERA 1, 2	...	Western Horizons
75	ASAP	..	Great Western Pet.
76	SHASTA 3-5	...	Newmont
77	VALRIE 1, 2	...	T. Pickell
78	MOYEZ 1-4, CHUCK 1, 2	...	Newmont
79	SPAR MOUNTAIN	...	C. Kowall
80	CASTLE MTN., CASTLE MTN. FR.	...	Dynamic Oil Co.
81	FOGHORN	...	Kidd Creek Mines
82	LEGHORN	...	Kidd Creek Mines
83	AWESOME	...	Kidd Creek Mines
84	GUARD	...	Newmont

The strike length of the Cliff Creek Breccia Zone is estimated to exceed 1.5 kilometres. Drilling including 19 holes in 1984, has tested about 200 metres of strike length near the northern end of the zone, where it is cut by a major northwesterly trending fault. In contrast to thin alteration haloes observed on veins in the AGB Zone, the Cliff Creek Zone has a significant clay alteration envelope around the ore zone; alteration extends for approximately 35 metres on each side of it.

The Duke's Ridge Zone has been traced by trenching, mapping, and limited diamond drilling along a total strike length of 1.2 kilometres. During 1984, 13 drill holes tested about 300 metres of strike length; the average width is 5 metres.

Trenching on the Marmot Lake occurrence, located 3 kilometres south along the structure which runs through the Cliff Creek Breccia Zone, confirmed the existence of significant mineralization; the occurrence was discovered in 1971 by Kennco.

The significant geologic difference between the Cliff Creek and Duke's Ridge Zones, and the AGB Zone is the host rock. The first two are hosted by megacrystic crystal tuffs and flows which are higher up in the stratigraphic section than the main host rocks at the AGB Zone which are quartzose andesitic and trachytic crystal tuffs. The basic ore mineralogy is the same for all three zones; fine-grained acanthite, electrum, native silver, and native gold in a predominantly quartz (±amethyst) gangue with minor amounts of carbonate.

A comprehensive feasibility study is scheduled to be carried out over the winter; a production decision may follow shortly thereafter.

(2) KIDD CREEK MINES LTD.

(a) JD (PIT) (Fig. 109, No. 50; Mineral Inventory 94E-31, 32, and 65); 330 metres of surface drilling was completed in seven holes on the Gasp and Gumbo Zones. Five backhoe trenches were completed on the Woof Zone for a total of 130 metres.

Mineralization in the Gasp Zone consists of native gold, native silver, galena, sphalerite, chalcopyrite, and pyrite in steeply dipping quartz ±calcite veins that occur in andesitic flow rocks. The zone is associated with a silicified and clay-altered low-angle fault zone. Quartz-calcite veins, which range from less than 1 to 200 millimetres thick, occur in propylitic andesite in the footwall McClair Creek Formation (informal name). These veins occur in a northwest-trending zone which has been traced along a 150-metre strike length and across a width of approximately 20 metres.

The Gumbo Zone, which has been traced for 400 metres along strike, is associated with the shallow-dipping (thrust) fault which marks the contact between the (hangingwall) Tuff Peak Formation and the (footwall)

McClair Creek Formation (informal names). Zones of clay-quartz alteration (yellow clay) are intermixed with zones of intense silicification in andesite. Sulphides include disseminated pyrite (up to 10 per cent) and trace amounts of galena, sphalerite, and acanthite. Erratic gold and silver mineralization is associated with zones of intense silicification and occurs in propylitic footwall rocks cut by quartz-carbonate veinlets.

(b) AL (RIDGE, BONANZA) (Fig. 109, No. 48; Mineral Inventory 94E-78, 79, 85); 1 211 metres of surface drilling was completed in 19 holes on Verrenass, Thesis II, Thesis III, and BV Zones. Approximately 40 backhoe trenches, totalling 2 012 lineal metres, were excavated; the majority are in the Thesis III and BV Zones.

Most mineralized zones (more than six in number) on the AL property consist either of structurally controlled, barite-gold mineralized alteration zones (for example, Verrenass, Thesis II, BV) or of silica-hematite-gold mineralized alteration zones (for example, Ridge, Thesis II, Golden Furlong (Fig. 109, No. 55; Mineral Inventory 94E-80). Host rocks consist of subhorizontal, dominately subaerial Jurassic andesitic to dacitic, or latitic ash flows, air-fall tuffs, and flows. Hydrothermal alteration is widespread and the volcanic rocks have undergone various degrees of diagenetic hematization. Zones of propylitic and argillic alteration also contain zeolites±chlorite±sericite and various clays (mainly dickite). Zones of silicification consist of quartz±alunite± dickite±barite±pyrite. Silica occurs in massive to banded to brecciated zones, and locally as veins.

The gold-silver mineralization is primarily associated with replacements of quartz-barite and quartz-hematite. It also occurs in drusy barite-quartz veins.

In the Verrenass Zone, argillic fiammé and plagioclase crystals in the silicified matrix of the host dacitic ash flow were leached prior to or during the influx of barite and gold-bearing solutions. Alteration minerals include quartz, sericite, hematite, dickite, montmorillonite, and barite. Sulphides include pyrite, native gold, and minor amounts of late-stage tennantite and secondary covellite. Gold-silver mineralization is erratic.

In the Thesis and BV Zones, native gold with replacement barite occurs in silicified zones that are flanked by zones of argillic alteration, similar to that at the Verrenass Zone. Gold-silver mineralization is erratic. Locally, brecciation is intense. The zones of Au-Ag mineralization and alteration apparently represent deposition in a high level epithermal system.

(3) NEWMONT EXPLORATION OF CANADA LTD.

(a) Shas (Fig. 109, No. 22; Mineral Inventory 94E-50); 2 002.2 metres of diamond drilling was carried out in 19 holes; holes range from 33 to 197 metres in length.

A large (400 by 500 metre) zone of silicification in Toodoggone crystal tuffs hosts the mineralization, which consists of native silver, acanthite, electrum, tetrahedrite, pyrite, chalcopyrite, galena, and sphalerite. Three potential mineralized zones (Creek, Main, and Upper) have been located along a northerly trend for more than 500 metres. Drilling during 1984 was concentrated on the Creek Zone. The mineralized zones occur near a fault contact between (hangingwall) grey crystal to lithic tuff and (footwall) orange quartz-eye feldspar tuff. The 'stockwork' mineralization forms a network of quartz±calcite veinlets in a quartz-eye tuff unit. Better grades are associated with chalcedonic breccia zones; appreciable lengths of low grade mineralization are associated with quartz vein stockworks.

(b) Golden Lion (Fig. 109, No. 67; Mineral Inventory 94E-77); 2 475 metres of diamond drilling was completed in 22 holes; holes range from 45 to 242 metres in length.

Three zones of mineralization (Zones 1, 2, and 3) were tested along a northwesterly trending strike length for a distance of 1 525 metres. Acanthite, chalcopyrite, galena, and sphalerite occur in a structurally complex quartz±barite vein system in host silicified Toodoggone dacitic tuffs. The zones are in close proximity to a major fault contact with Takla Group andesites. Assays up to 22 100 ppm (650 ounces per ton) silver have been recorded. Gold values are consistently low.

In Zone 3, a subvolcanic (crowded porphyry) intrusion cuts the sequence. The geological setting and mineralogy are similar to that of the Porphyry Pearl prospect, which is located near the junction of McClair and Moosehorn Creeks a few kilometres to the south. There, galena-sphalerite ±precious metals occur in a quartz veinlet stockwork. Potassic alteration exists both within the host rock matrix and in vein selvages; the host rock lacks quartz.

(4) ST. JOE CANADA INC.
Silver Pond (Fig. 109, No. 41; Mineral Inventory 94E-69); 940 metres of lineal trenching was done.

The property adjoins SEREM's Lawyers property on the west. The Cloud Creek Zone (Mineral Inventory 94E-75) and the possible southwesterly extension of SEREM's Cliff Creek Breccia Zone were the main areas of interest. Host rocks include coarse pyroclastic rocks and flows of the Toodoggone volcanics.

(5) PACIFIC RIDGE RESOURCES CORP.
Ron Claims (Fig. 109, No. 64); a small diamond-drill program was conducted to test a large (700 by 600 metres) sulphide system. Large faults have been located and may host significant precious metal zones. Barite float has been found.

(6) ARK ENERGY LTD.
Ark Claims (Fig. 109, No. 11); soil sampling indicated a precious metal anomaly along a north-south fault zone.

(7) DU PONT OF CANADA EXPLORATION LTD./COMINCO LTD.
Bill Claims; 1 848.4 metres of surface drilling was carried out in nine holes located primarily in the region of 1983 drilling.

Native gold mineralization occurs within quartz and arsenopyrite± carbonate veins, usually at the contacts of a quartz-muscovite schist in greenstone; mineralization commonly extends into the overlying or underlying greenstone. The predominate vein and structural orientations are now known to be nearly east-west; previously they were thought to be north-south. Several high grade but narrow drill intersections with gold values were encountered.

ACKNOWLEDGMENTS

The writer would like to acknowledge the hospitality and logistical support offered in the field by the following companies: Newmont Exploration of Canada Limited, Kidd Creek Mines Ltd., SEREM Inc., St. Joe Canada Inc., Central Mountain Air Services Ltd., and Airlift Corporation.

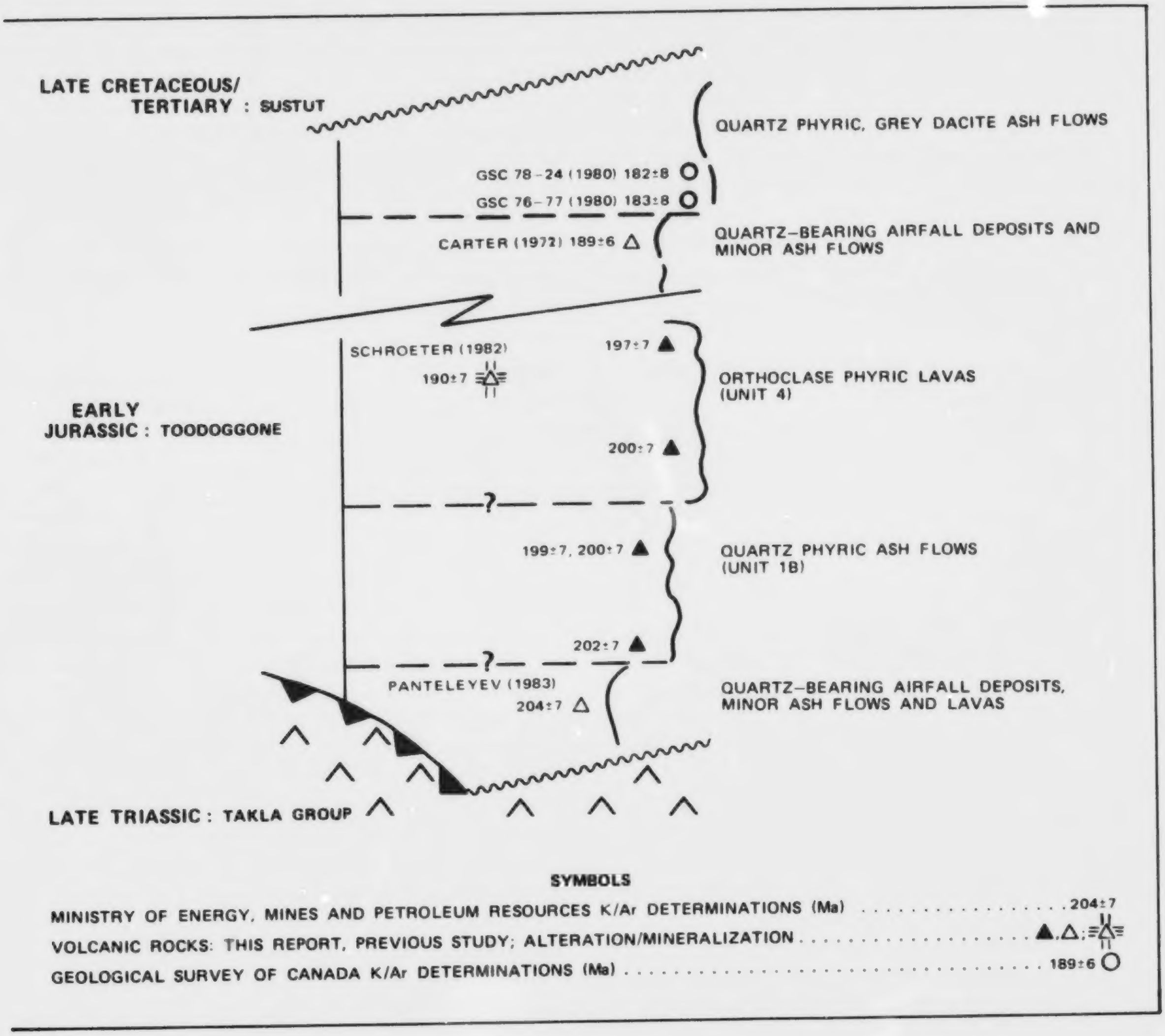

LATE CRETACEOUS/
TERTIARY : SUSTUT
QUARTZ PHYRIC, GREY DACITE ASH FLOWS
GSC 78-24 (1980) 182±8
GSC 76-77 (1980) 183±8
CARTER (1972) 189±6
QUARTZ-BEARING AIRFALL DEPOSITS AND MINOR ASH FLOWS
SCHROETER (1982)
190±7
197±7
ORTHOCLASE PHYRIC LAVAS (UNIT 4)
EARLY
JURASSIC : TOODOGGONE
200±7
?
199±7, 200±7
QUARTZ PHYRIC ASH FLOWS (UNIT 1B)
202±7
?
PANTELEYEV (1983)
204±7
QUARTZ-BEARING AIRFALL DEPOSITS, MINOR ASH FLOWS AND LAVAS
LATE TRIASSIC : TAKLA GROUP
SYMBOLS
MINISTRY OF ENERGY, MINES AND PETROLEUM RESOURCES K/Ar DETERMINATIONS (Ma) . . . . 204±7
VOLCANIC ROCKS: THIS REPORT, PREVIOUS STUDY; ALTERATION/MINERALIZATION . . . . ▲,△;≡△≡
GEOLOGICAL SURVEY OF CANADA K/Ar DETERMINATIONS (Ma) . . . . 189±6 ○

Figure 110. Schematic composite stratigraphic section illustrating the relative position of major Toodoggone lithologic units from which K/Ar radiometric dates have been obtained.

POTASSIUM-ARGON AGE DETERMINATIONS FROM BIOTITE AND HORNBLENDE IN TOODOGGONE VOLCANIC ROCKS

(94E)

By L. J. Diakow

Five new K/Ar determinations have been obtained from two volcanic flow units underlying the area between Todoggone and Chukachida Rivers. The sample locations and ages are tabulated in Table 1 and their relative stratigraphic position within the Toodoggone succession are shown on Figure 110. These data supplement field mapping conducted in the area by the writer in 1983.

The older of the two flow units, designated as map unit 1B (Diakow, 1984), comprises biotite-hornblende-plagioclase phyric ash flow sheets containing 1 to 3 per cent modal quartz. K/Ar ages for unit 1B are 202±7 Ma from biotite and concordant ages of 199±7 and 200±7 Ma from coexisting biotite and hornblende respectively. Flows of map unit 4 conformably overlie unit 1B west of Tuff Peak. Characteristically these flow rocks contain sparse, coarse-grained orthoclase phenocrysts but lack significant quartz phenocrysts. Two samples of biotite from unit 4 yielded K/Ar dates of 197±7 and 200±7 Ma.

In addition to the existing K/Ar dates from volcanic rocks summarized on Figure 110, five new determinations are in progress and will be reported later. These samples include: a hornblende porphyritic basaltic intrusive rock, a rhyolite flow, and three samples of adularia alteration associated with mineralization.

REFERENCES

Carter, N. C. (1972): Toodoggone River Area, *B.C. Ministry of Energy, Mines & Pet. Res.*, GEM, 1971, pp. 63-70.

Diakow, L. J. (1984): Geology between Toodoggone and Chukachida Rivers, *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1983, Paper 1984-1, pp. 139-145.

Gabrielse, H., Wanless, R. K., Armstrong, R. L., and Erdman, L. R. (1980): Isotopic Dating of Early Jurassic Volcanism and Plutonism in North-central British Columbia, *in* Current Research, Part A, *Geol. Surv., Canada*, Paper 80-1A, pp. 27-32.

Panteleyev, A. (1983): Geology between Toodoggone and Sturdee Rivers, *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1982, Paper 1983-1, pp. 142-148.

Schroeter, T. G. (1982): Toodoggone River, *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1981, Paper 1982-1, pp. 122-133.

TABLE 1
POTASSIUM-ARGON DETERMINATIONS FROM BIOTITE, HORNBLENDE, AND NATROALUNITE IN TOODOGGONE VOLCANIC ROCKS

Sample	Location Longitude	Location Latitute	Mineral	K_2O %	$^{40}Ar^*$ 10^{-10} moles/gm	$^{40}Ar^*$ %	Apparent Age (Ma) ±10	Lithology	Reference
292-1	127°20'18"	57°26'58"	Biotite	6.19	22.76	93.6	200±7	Unit 4	
268-3A	127°30'12"	57°31'38"	Biotite	5.57	20.09	95.6	197±7	Unit 4	
266-5	127°32'24"	57°32'24"	Biotite	6.34	23.09	94.4	199±7	Unit 1B	
266-5	127°32'24"	57°32'24"	Hornblende	0.81	2.97	65.7	200±7	Unit 1B	
274-4	127°20'24"	57°32'45"	Biotite	6.83	25.33	96.6	202±7	Unit 1B	
81AP-T28	126°39'30"	57°05'38"	Biotite	6.87	25.74	97.5	204±7		Panteleyev (1983)
NC-71-1	126°43'00"	57°07'36"	Hornblende	0.873	3.02	91.3	189±6		Carter (1972)
T81-191	127°24'54"	57°28'34"	Whole Rock	2.79	9.71	95.2	190±7		Schroeter (1982)

*radiogenic Ar

Constants: $\lambda^{40}K_{\epsilon} = 0.581 \times 10^{-10}$ yr^{-1}; $\lambda^{40}K_{\beta} = 4.96 \times 10^{-10}$ yr^{-1}; $^{40}K/K = 1.167 \times 10^{-4}$

%K determined by the Analytical Laboratory, British Columbia Ministry of Energy, Mines and Petroleum Resources, Victoria

Ar determination and age calculation by J. E. Harakal, University of British Columbia

STREAM SEDIMENT SAMPLING OF THE WOKKPASH PARK PROPOSAL AREA (94K/7)

By A. Legun

A five-day stream sediment sampling program was undertaken in the Wokkpash Park Proposal Area in August. The area, which encloses the watershed of Wokkpash Creek, is located 32 kilometres due south of mile 400 on the Alaska Highway (Fig. 111, page 302). This year's work complements previous geological ground observations (Legun, 1984). The abandoned Racing River road was washed out, so it was necessary to walk into the Wokkpash Valley from a point near the Alaska Highway.

To minimize the cost of flying, valley bottom sites were accessed by foot and samples cached periodically during a traverse to the end of the valley. Alpine areas were sampled and caches retrieved by helicopter, just before flying out.

Sample sites included Wokkpash Creek and all major tributaries (Fig. 111). A total of 44 samples were collected. In the main valley, tributaries were sampled on foot; samples are sited at the tops of alluvial fans where the tributaries exit their bedrock valleys or canyons. Silt-sized sediment of sufficient volume was difficult to obtain. Glacial debris transported from outside the immediate watershed frequently contaminated samples. In several instances the composition of alluvial rubble contrasted sharply with that of adjacent bedrock.

Analyses for gold, silver, copper, lead, zinc, cobalt, nickel, barium, and fluorine are underway; results are expected by early 1985. This quantitative data should facilitate an appropriate land use decision to be made for this proposed park area.

REFERENCE

Legun, A. (1984): Geologic Reconnaissance of the Wokkpash Park Proposal Area (94K), *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1983, Paper 1984-1, pp. 146-148.

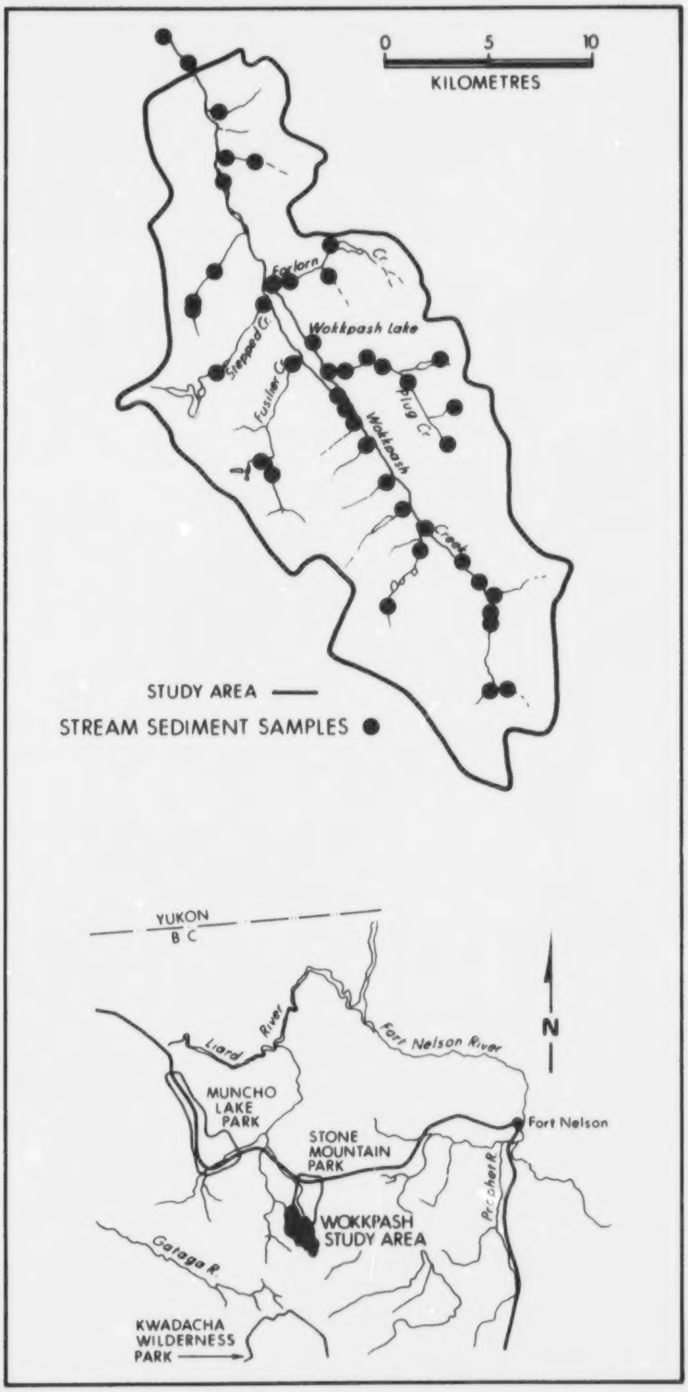

0
5
10
KILOMETRES
Forlorn
Cr.
Stepped Cr.
Fusilier Cr.
Wokkpash Lake
Plug Cr.
Wokkpash
Creek
STUDY AREA ——
STREAM SEDIMENT SAMPLES ●
YUKON
B C
Liard
River
Fort Nelson River
N
MUNCHO
LAKE
PARK
STONE
MOUNTAIN
PARK
Fort Nelson
Prophet R.
WOKKPASH
STUDY AREA
Gataga R.
KWADACHA
WILDERNESS
PARK

Figure 111. Location map and stream sediment sampling sites, Wokkpash Park Proposal area.

KALUM PROPERTY (TREADWELL)
(103I/15W)

By T. G. Schroeter

INTRODUCTION

The Kalum claim group, which is located on the east side of Kitsumkalum Lake approximately 35 kilometres north-northwest of Terrace, encompasses the old Treadwell, Belway, and Rex properties (Mineral Inventory 103I-118). Access to the property is by a recently paved (1984) road that connects Terrace to Rosswood, then by gravel beyond that to Aiyansh and other communities in the Nass Valley.

The property comprises two 2-post claims owned by Cecil Pratt and one 15-unit claim owned by Fred Loutitt; both owners are from Terrace.

HISTORY

The main showings were originally staked in 1914 as the Treadwell No. 2 and Juneau claims. In 1931 they were restaked as the Moloya and Lake Shore claims and in 1937 as the Belway and Rex claims. Development work during this period consisted of a few pits, one shallow shaft, and two short adits. The only recorded work within the area of the claims subsequent to 1937 was in 1981 by Silver Standard Mines Ltd., who carried out minor soil and rock sampling, and geological mapping.

PROPERTY GEOLOGY

The Kalum claim group is underlain by a sequence of metavolcanic and metasedimentary rocks of probable Jurassic age. The volcanic rocks consist of dacitic crystal tuffs, which have undergone varying degrees of alteration to sericite, epidote, and chlorite, and meta-andesite to metabasalt in the vicinity of the shaft and north adit that are altered to mafic biotitic and chloritic schists and gneisses. These units are inter-bedded, well foliated, and locally strongly laminated. Some varieties contain epidote-rich bands up to 10 centimetres in width. The rock units strike predominately east-west and dip gently at 25 to 35 degrees to the north.

MINERALIZATION

Bornite and chalcopyrite with low gold and silver values occur locally in narrow shear zones in quartz stringers; in quartz-epidote-hematite lenses, pods, and veins; and in magnetite-rich, partly silicified tuff

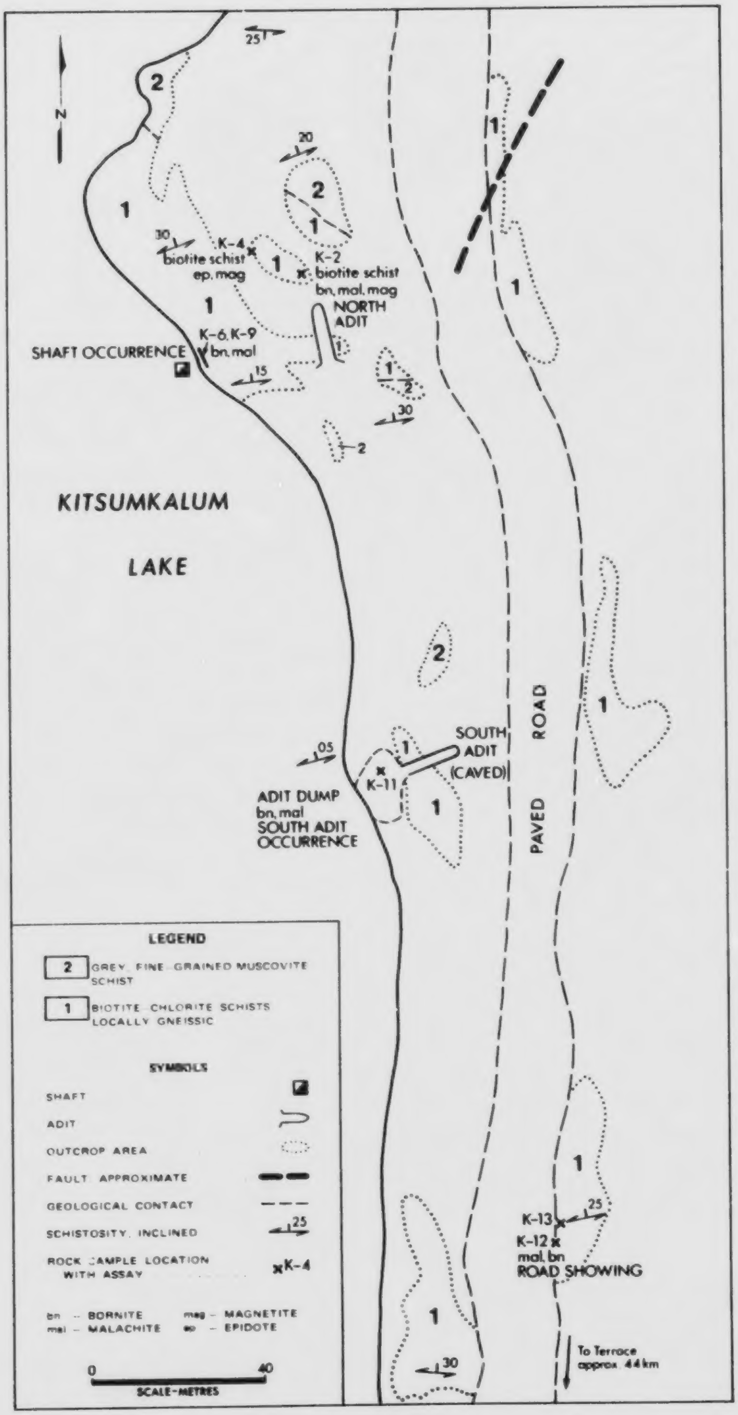

N
KITSUMKALUM
LAKE
PAVED ROAD
SHAFT OCCURRENCE
K-6, K-9
bn, mal
K-4
biotite schist
ep, mag
K-2
biotite schist
bn, mal, mag
NORTH
ADIT
SOUTH
ADIT
(CAVED)
K-11
ADIT DUMP
bn, mal
SOUTH ADIT
OCCURRENCE
K-13
K-12
mal, bn
ROAD SHOWING
To Terrace
approx. 44 km
1
2
25
20
30
15
05
LEGEND
2 GREY FINE-GRAINED MUSCOVITE SCHIST
1 BIOTITE CHLORITE SCHISTS LOCALLY GNEISSIC
SYMBOLS
SHAFT
ADIT
OUTCROP AREA
FAULT APPROXIMATE
GEOLOGICAL CONTACT
SCHISTOSITY, INCLINED
ROCK SAMPLE LOCATION WITH ASSAY
bn – BORNITE
mal – MALACHITE
mag – MAGNETITE
ep – EPIDOTE
0
40
SCALE-METRES

Figure 112. Plan of part of Kalum property.

bands. In the biotite and chlorite schist unit, bornite and chalcopyrite occur along planes of schistosity. Three principal showings have been located:

(1) Shaft Occurrence

A shaft, which is now completely filled in, is located a few metres from Kitsumkalum Lake and is prone to flooding every year. The shaft is collared in metabasalt, a few metres above an inferred contact with muscovite schist. Minor amounts of malachite occur in a few fractures, quartz stringers, and narrow shears. A sample taken from the shaft in 1914 reportedly assayed 0.42 ounce gold per ton and 0.5 ounce silver per ton across 8 feet (*Minister of Mines, B.C.*, Ann. Rept., 1915). The values apparently were in free gold, but no free gold was observed during the visit, nor has it been reported in recent times. Twenty-five metres east of the shaft an adit (north adit on Fig. 3, p. 14, Kindle, 1937) was driven for 13 metres on a bearing of 345 degrees (see Fig. 112).

TABLE 1
ASSAYS OF SAMPLES FROM KALUM PROPERTY

Sample No.	Description	Au ppm	Ag ppm	Cu ppm
K-2	biotite schist with stratbound bornite and magnetite	<0.3	ND	710
K-4	massive epidote with veinlets of magnetite	<0.3	ND	45
K-6	chip sample across 1.8 metres in biotite-chlorite schist	0.7	-	825
K-9	continuation of chip sample No. 6 across 3 metres	0.3	<10	250
K-11	banded epidote-biotite gneiss with stringers of bornite	0.3	14	0.78%
K-12	chlorite schist with stratabound bornite	<0.3	10	1.08%
K-13	bornite-epidote-rich skarn	4.1	100	4.80%

(2) South Adit Occurrence

The south adit was driven 110 metres southeast of the shaft area on a bearing of 070 degrees. The adit appears to have been driven along two, steeply dipping narrow shear zones which locally contain minor amounts of malachite.

In the adit dump area abundant malachite staining occurs in a siliceous, light-coloured, epidote-rich, biotite gneiss. A sample of 'high grade' assayed 0.3 ppm gold, 14 ppm silver, and 0.78 per cent copper (K-11, Table 1). The mineralized unit is highly magnetic with bands of magnetite parallel to the banding and foliation. Bornite and chalcopyrite, in amounts up to 3 per cent, occur both as disseminations, blebs and irregular veinlets, and in epidote-quartz-hematite veins and pods. Apparently a representative grab sample of the south adit mineralization was tested by the Mines Branch at Ottawa in 1931 and assayed 0.24 ounce gold per ton and 0.34 ounce silver per ton (Kindle, 1937, p. 15).

(3) Road Showing

The road showing is located approximately 85 metres south-southeast of the south adit. The area was recently stripped and opened up as part of the preparation for paving the road, which now goes through the property. Mineralization consists of bornite, specular hematite, and minor amounts of chalcopyrite in fractures, veinlets, and clots; as disseminations; and in quartz-epidote lenses within a dark grey, magnetite-rich silicified biotite gneiss. Epidote bands and laminations occur locally. The mineralized zone, which parallels the gneissosity, strikes east-northeast and dips 20 degrees to the north. Two grab samples assayed <0.3 ppm gold and 1.08 per cent copper, and 4.1 ppm gold, 100 ppm silver, and 4.80 per cent copper (K-12, K-13, Table 1).

COMMENTS

The mineralization, which is associated with magnetite-rich, partly silicified tuff bands and gneisses, appears to be stratabound; it may be of syngenetic origin with subsequent remobilization during regional deformation and metamorphism. Alternatively, mineralization may have occurred as a result of remobilization related to emplacement of the nearby Coast Intrusions. Higher grade gold values associated with reported free gold occur in crosscutting quartz veinlets that may represent a later period of mineralization that presumably is also related to the metamorphic event.

REFERENCES

B.C. *Ministry of Energy, Mines & Pet. Res.*, Ann. Rept., 1915, pp. 105-107; 1919, pp. 49, 50; 1927, p. 63; 1931, p. 36; 1967, p. 53.

B.C. *Ministry of Energy, Mines & Pet. Res.*, Assessment Report 11595.

Duffell, S. and Souther, J. G. (1964): Geology of Terrace Map-area, British Columbia (103I/E 1/2), *Geol. Surv., Canada*, Mem. 329, 117 pp.

Kindle, E. D. (1937): Mineral Resources of Terrace Area, Coast District, British Columbia, *Geol. Surv., Canada*, Mem. 205, 60 pp.

GEOLOGY OF THE SPIDER CLAIM GROUP ON LONG LAKE

(104A/4)

By Jacques P. Dupas

INTRODUCTION

This study describes geology and mineralization in the vicinity of the 'Glacier Creek augite diorite intrusive' and the Spider claim group (Mineral Inventory 104A-010). The work included detailed mapping (1:10 000) of a 1.5-square-kilometre area surrounding the Spider workings. The main adit was blocked by snow but sulphide-bearing samples from dumps near the upper and lower adits were collected for study. Augite porphyry from the lower adit was collected for radiometric dating and whole rock analysis. Grab samples of pyritic strata were submitted for assay.

HISTORY

The Spider claim group, Lots 4172 to 4174, was first staked in 1918 by Bill Hamilton and Charlie Larsen of Stewart. Trites & Wood, part owners of the Premier mine, optioned the property in early 1919 but did little work on it. Later that year the option was acquired by the Algunican Development Company of Brussels, Belgium. In 1920, under the local management of W. A. Meloche and the supervision of John Hoveland, a camp was constructed on the Spider property to carry out exploration including: diamond drilling, two open cuts on an exposed vein, and a 215-metre adit on another vein. These excavations are still intact. Algunican Development dropped the option at the end of 1920.

In 1924, the claims were Crown-granted to Hamilton and Larsen. B.C. Bonanza Mines Limited optioned the ground in 1925 and mined and shipped 6.35 tonnes (7 tons) of ore with grades averaging 15.4 grams gold per tonne (0.45 troy ounce per ton) and 12 700 grams silver per tonne (371 troy ounces per ton), with some lead and zinc values. Exploratory work was done on two new veins.

In 1933, the property was allowed to lapse for taxes and was purchased from the government by Theo Collart and associates of Prince Rupert. The property was then leased to O. McFadden and another Stewart miner, who mined a total of 15.9 tonnes (17.5 tons) over the next three years with grades averaging 13.7 grams gold per tonne (0.40 troy ounce per ton) and 6 400 grams silver per tonne (188 troy ounces per ton).

As of May, 1984, Marie Burnett of Stewart owned Lot 4172, Spider No. 1 claim, and Carl E. Wickstrom of Vancouver owned Lots 4173 and 4174, Spider Nos. 2 and 3 claims.

REGIONAL GEOLOGY

The region lies near the western edge of the Intermontane Belt close to the contact with the Coast Plutonic Complex. The Spider claim group is at the contact of the Betty Creek and the Salmon River Formations (Grove, 1983) or of map units 2, 3, and 4 of Alldrick (this volume). Fossils indicate that the strata are of Middle Jurassic age (Grove, 1973). The older Betty Creek Formation consists of red, purple, green, and black volcanic breccia, conglomerate, sandstone, and siltstone, described following as unit 2. The Salmon River Formation (Grove, 1983) includes a basal felsic volcanic sequence overlain by siltstones, greywackes, sandstones, some calcarenite, and minor amounts of limestone, argillite, and conglomerate, described following as units 3, 4, 5, and 6. The augite porphyry rock within the map-area has been interpreted as an intrusive stock by previous workers (Schofield and Hanson, 1922; Hanson, 1929, 1935; Grove, 1971, 1973, 1983), and is described following as unit 1.

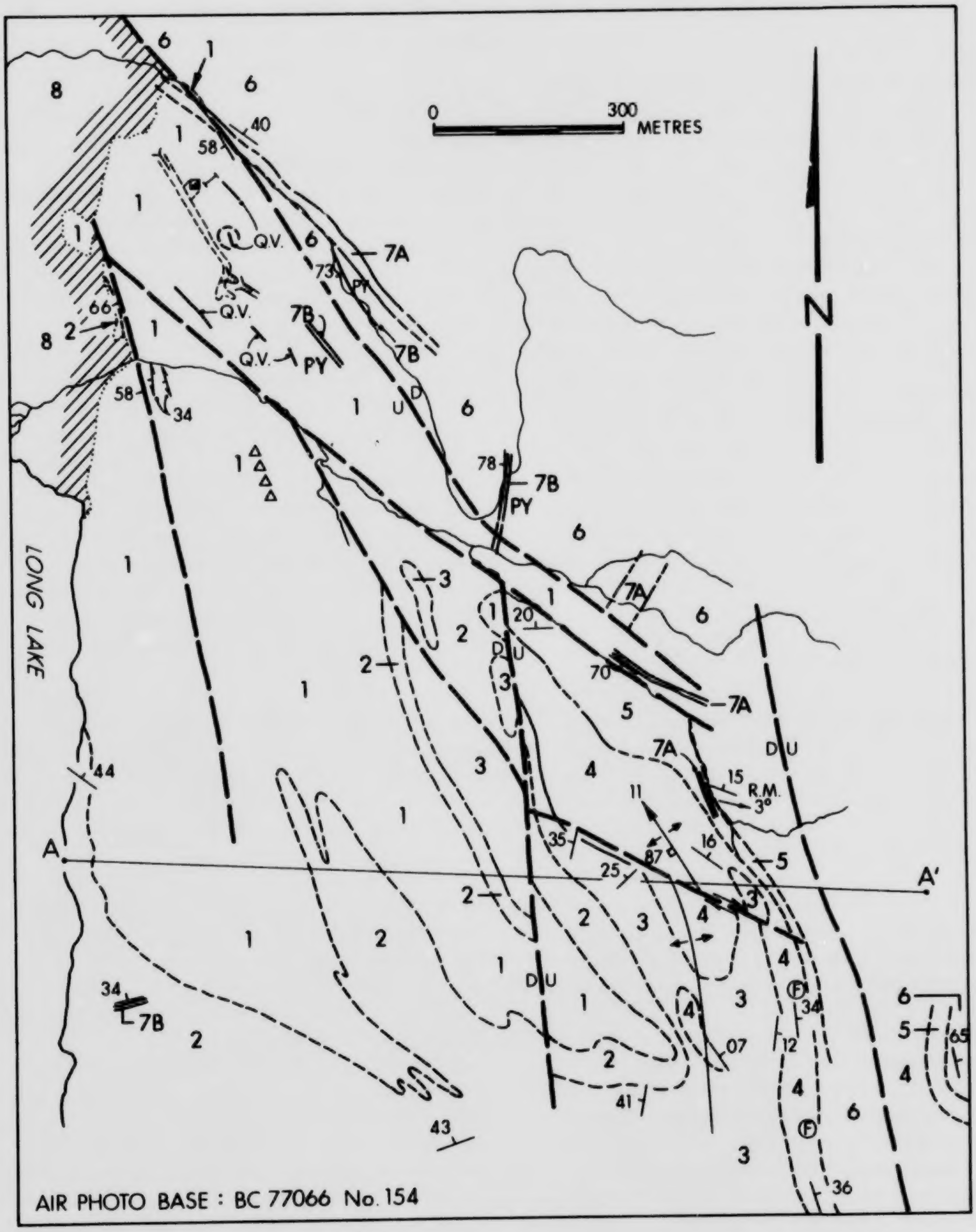
All the previously mentioned rocks are intruded by the Tertiary Portland Canal dyke swarm; the dykes range in composition from granite to quartz diorite. Structurally, the map region lies on the eastern limb of the canoe-shaped, doubly plunging, north-trending Dillworth syncline.

STRATIGRAPHY

The stratigraphic sequence in the map-area consists of a massive augite porphyry unit overlain by an epiclastic sedimentary unit. These are overlain by a sequence of felsic volcanic rocks capped by dark grey and black siltstones (Fig. 113). The succession has been deformed and intruded by Tertiary Portland Canal dykes. Surficial deposits in the map-area include alluvium, lacustrine deposits, and moraines.

The epiclastic sedimentary rocks and all the felsic volcanic units contain fragments of augite porphyry, indicating that the augite porphyry is older and was eroding when the Middle Jurassic succession was deposited.

The contact between the massive augite porphyry and the overlying epiclastic sediments resembles an *in situ* weathered bedrock profile. At this contact the massive augite porphyry grades upward into a fractured porphyry and then into a rock with angular fragments of porphyry in a gritty matrix. There is a sharp contact at the top of this gradational zone with overlying conglomerate which consists of rounded augite porphyry cobbles in a gritty matrix. The sharp contact and the rounded fragments suggest that water-reworked strata were deposited above an *in situ* weathered sequence. With the possible exception of the pyritic rhyolite lapilli tuff-sandstone contact, which was not observed in the map-area, the remaining contacts are all conformable.



0
300 METRES
N
LONG LAKE
8
6
1
Q.V.
7A
7B
PY
2
3
4
5
U
D
R.M.
3°
A
A'
F
40
58
73
66
34
78
20
70
15
11
16
87
35
25
44
07
12
41
43
36
65
AIR PHOTO BASE : BC 77066 No. 154

Figure 113. Geology of the Spider claim group on Long Lake, Stewart, British Columbia.

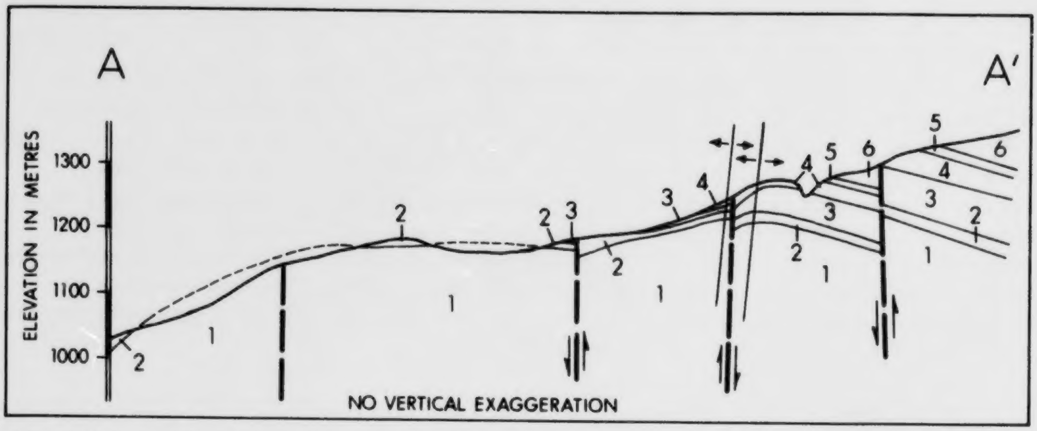


Figure 114. Geological cross-section A-A', Spider claim group (see Fig. 113 for location).

LEGEND

8	ALLUVIUM, LACUSTRINE SANDS AND SILTS, AND GLACIAL MORAINES
7	DYKES A HORNBLENDE–FELDSPAR PORPHYRY (GRANODIORITIC) B FINE–GRAINED MASSIVE GRANODIORITE
6	SILTSTONES
5	PYRITIC RHYOLITE LAPILLI TUFFS
4	RHYOLITE LAPILLI TUFFS
3	DUST TUFFS WITH OCCASIONAL FRAGMENTS OF AUGITE PORPHYRY
2	EPICLASTICS
1	MASSIVE AUGITE (± FELDSPAR) PORPHYRY, (Δ BRECCIATED)

SYMBOLS

ADIT WITH PLAN OF UNDERGROUND WORKINGS ....

OPEN CUT, WITH ADIT PORTAL ....

INCLINED SHAFT ....

STRIKE AND DIP OF EITHER CONTACT OR BEDDING ....

FAULT; U = UP FAULTED SIDE; D = DOWN FAULTED SIDE .... U D

INFERRED CONTACT ....

MAPPED CONTACT ....

QUARTZ VEIN .... Q.V.

PLUNGE AND TREND OF A RIPPLE MARK .... →3 R.M.

STRIKE AND DIP OF A FOLIATION ....

STRIKE AND DIP OF A FAULT 66

FOSSIL LOCATION .... Ⓕ

ANTICLINE, SHOWING TRACE OF AXIAL PLANE, PLUNGE OF AXIS, AND DIP OF AXIAL PLANE .... 87° 11

DAM LOCATION ....

UNIT 1 - MASSIVE AUGITE PORPHYRY

This rock consists of euhedral green-black phenocrysts of augite in an aphanitic, medium grey to olive green matrix. Augite phenocrysts range in size from 2 to 8 millimetres, often showing an eight-sided cross-section on fresh rock surfaces (*see* Grove, 1971, Plate XIVA). In a few areas small crystals of feldspar, less than 1 millimetre, are present in the matrix. Some of the large greenish black phenocrysts appear to be pseudomorphs of chlorite after augite. The augite porphyry may be a flow as indicated by an overall dense, massive texture. A narrow brecciated zone, possibly a flow breccia or feeder pipe, occurs in the central area of the augite porphyry.

The mineralized quartz veins, for which Spider claims were staked, are hosted in intensely sheared zones of the massive augite porphyry.

UNIT 2 - EPICLASTIC ROCKS

Rocks in the epiclastic unit range from siltstones to cobble conglomerate. In general, clasts in the epiclastic unit are mainly felsic volcanic rocks but toward the lower contact with the augite porphyry, clasts are predominantly augite porphyry. Rock fragment sizes range from bed to bed within the unit; they vary from grit size to cobbles 15 centimetres in diameter. The rock is typically a purplish, hematitic colour but may also be bright medium green.

UNIT 3 - DUST TUFF

The dust tuff is a massive aphanitic siliceous rock. Rare, rounded fragments of augite porphyry occur in the upper part of the unit near the contact with overlying felsic lapilli tuff. The colour ranges from purple to light green or light grey. The rock fractures into angular pieces with sharp corners and smooth planar faces which have a greasy to waxy lustre. This unit appears to thicken to the east, changing from 8 metres in the central part of the map-area to more than 40 metres in the east (Fig. 114).

UNIT 4 - RHYOLITE LAPILLI TUFF

The rhyolite lapilli tuff unit is approximately 20 to 30 metres thick. The tuffs lie conformably between unit 5, pyritic rhyolite lapilli tuffs, and unit 3, dust tuffs. Lapilli in unit 4 range from 2 to 15 centimetres in diameter and are hosted in a fine-grained, light grey matrix. The clasts consist of an assemblage of rhyolitic fragments as well as some clasts of augite porphyry. Both rhyolite and augite porphyry fragments are angular, suggesting minimal reworking after deposition. A thin bed of fossiliferous impure limestone, located a metre below the upper contact of this unit, hosts fragments of belemnites and pelecypods as well as silty mud balls or rip-up clasts.

UNIT 5 - PYRITIC RHYOLITE LAPILLI TUFF

Except for the presence of disseminated pyrite, this 2-metre-thick unit is identical to the rhyolite lapilli tuff described previously as unit 4. Pyrite occurs in both the clasts and the matrix. Heterolithic fragments include silty limestone blocks that are up to 1 metre in diameter. The pyrite produces a characteristic heavily iron-stained weathered surface.

UNIT 6 - SILTSTONES

Unit 6 consists of interbedded siltstones and fine-grained sandstones in layers 5 to 10 centimetres thick. The rocks are pyritic in many places producing the characteristic banded, iron-stained weathered surfaces that allow easy identification. The thickness of this unit could not be determined in the map-area. Ripple marks, recorded in the northeast corner of the mapped area at the base of the siltstone unit, display an amplitude of 2 centimetres and a wavelength of 8 centimetres. Stratigraphic tops are upright; the siltstone strikes 115 degrees and dips 15 degrees north-northeast; the ripple marks plunge 03 degrees toward 105 degrees.

UNIT 7 - DYKES

Hornblende-feldspar Porphyry

This dyke-rock type is characterized by phenocrysts of white euhedral plagioclase approximately 5 to 10 millimetres in length, and slender, dark green euhedral hornblende approximately 3 to 8 millimetres long in a fine-grained light grey groundmass. Some dykes also have small phenocrysts of euhedral potassic feldspar, usually less than 2 millimetres long.

Aphanitic Diorite

A lack of phenocrysts and a medium green to light grey colour distinguish this dyke-rock type. Some of these dykes carry up to 2 per cent fine, disseminated pyrite.

STRUCTURE

Beds in the eastern part of the map-area are folded forming an anticline plunging 7 to 11 degrees northerly at 005 degrees azimuth. The axial surface of this fold dips 87 degrees easterly; limbs are sharply flexed containing an interlimb angle of about 74 degrees. The size and attitude of this fold indicates that it may be a second-order flexure parasitic to the main Dillworth syncline to the west.

The fold axial trace is offset by a right lateral fault that strikes west-northwest (Fig. 113). Other faults in the area strike northerly and northwesterly. Movements shown by offset contacts are right lateral on northwesterly and vertical on northerly faults; at least two periods of faulting occurred. An example of vertical offset is the small fault block immediately northwest of the fold axis. This block has dropped relative to the strata to the east and to the south, so unit 3 the dust tuff just caps the hills on the block.

A tongue of epiclastic conglomerate overlies the massive augite porphyry in the fault block in the southwest part of the map-area. Two possible structural interpretations are: a syncline with an erosional remnant of epiclastic strata preserved along the fold axis, or a paleotopographic low on the augite porphyry paleosurface with epiclastic rocks filling this depression.

Dykes in the mapped area generally trend either north or northwest. The dykes are found along axial surfaces in the folded siltstones, along faults in the massive augite porphyry, and filling contact faults. This suggests dyke intrusion postdated much tectonic activity, including the major period of folding.

MINERALIZATION

Study of sulphide mineralization in the map-area was limited to surface examination of the quartz veins and dump material from the Spider adits. Quartz veins on the Spider claim group are numerous and range in size from narrow stringers to veins up to 2 metres wide with a strike length of several tens of metres. For vein locations, *see* Figure 113 or, for a more detailed map, refer to the 1936 British Columbia Ministry of Mines Annual Report, page B29. Sulphides noted in samples from the upper adit include argentite, sphalerite, galena, chalcopyrite, and pyrite.

CONCLUSION

The augite porphyry body at the north end of Long Lake, formerly identified as a Tertiary age stock, is now thought to be a Middle Jurassic or older augite porphyry lava flow. Intrusion of the dykes in the map-area evidently postdated folding because they cut a parasitic anticline revealed by this mapping project.

ACKNOWLEDGMENTS

Many thanks to Dani Alldrick for his help in the geologic mapping of the area and the advice he gave with respect to this report. Helicopter support was provided by Don Phippin of Vancouver Island Helicopters.

REFERENCES

Alldrick, D. J. (1983): Salmon River Project, Stewart, British Columbia (104B/1), *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1982, Paper 1983-1, pp. 182-195.

.... (1984): Geologic Setting of the Precious Metal Deposits in the Stewart Area (104B/1), *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1983, Paper 1984-1, pp. 149-164.

Grove, E. W. (1971): Geology and Mineral Deposits of the Stewart Area, British Columbia, *B.C. Ministry of Energy, Mines & Pet. Res.*, Bull. 58.

.... (1973): Geology and Mineral Deposits of the Stewart Complex, British Columbia, unpub. Ph.D. thesis, *McGill Univ.*, 434 pp.

.... (1983): Geology of the Unuk River-Salmon River-Anyox Map-area, *B.C. Ministry of Energy, Mines & Pet. Res.*, Miscellaneous Map Series (coloured maps to accompany Bull. 63, in preparation).

Hanson, G. (1929): Bear River and Stewart Map-areas, Cassiar District, British Columbia, *Geol. Surv., Canada*, Mem. 159, 84 pp.

.... (1935): Portland Canal Area, British Columbia, *Geol. Surv., Canada*, Mem. 175, 179 pp.

Minister of Mines, B.C.,: Ann. Rept. 1919, p. 77; 1920, p. 65; 1922, p. 83; 1923, p. 81; 1925, p. 106; 1934, p. B27; 1936, pp. B28-B31.

O'Neill, J. J. (1919): Salmon River District, Portland Canal Mining Division, British Columbia, *Geol. Surv., Canada*, Summ. Rept., 1919, pp. 7B-12B.

Schofield, S. J. and Hanson, G. (1922): Geology and Ore Deposits of Salmon River District, British Columbia, *Geol. Surv., Canada*, Mem. 132.

STRATIGRAPHY AND PETROLOGY OF THE STEWART MINING CAMP
(104B/1)

By D. J. Alldrick

INTRODUCTION

This report summarizes stratigraphic and intrusive relationships in the Salmon River valley which trends north of Stewart for 35 kilometres (Fig. 115). Mineral deposits in the area show stratigraphic relationships that may provide exploration guides.

VOLCANIC AND SEDIMENTARY ROCKS

Significant revisions have been made to the stratigraphic column of Alldrick (1984, Fig. 58; *see* Table 1A, Fig. 116). These revisions include recognition of porphyritic andesite flows and regional siltstone marker beds within the andesite sequence, and subdivision of 'map unit 4 - transition sequence' into separate black tuff and sedimentary units.

MAP UNIT 1 - ANDESITE SEQUENCE (AS)

The andesite volcanic sequence is composed of massive, green to greenish grey tuff with minor amounts of interbedded siltstone, epiclastic rocks, and volcanic flows. The fragmental volcanic rocks range from dust to ash tuff, crystal tuff, lapilli tuff, and pyroclastic breccia.

The tuffs show no evidence of either sorting within individual beds, or preferred orientation of crystals or lithic fragments. Hematitic epiclastic lenses are interbedded with the andesite tuffs. The sequence represents a predominantly subaerial accumulation with two periods of submergence marked by the regionally developed interbedded black siltstone members.

Volcanic Flows (1f, 1g)

Bimodal, feldspar-porphyritic andesite flows (1g) outcrop along the bottom of Summit Lake, along the west side of Mount Dillworth, and uphill from the Silbak Premier minesite (Fig. 115). Phenocrysts comprise small (3 to 5-millimetre) white, subhedral to euhedral plagioclase crystals and larger (1 to 5-centimetre) buff-coloured, euhedral orthoclase crystals; locally, 5 to 10-millimetre hornblende crystals occur; the matrix is fine grained. The Summit Lake and Mount Dillworth exposures are probably parts of the same flow, indicating a minimum strike length of 4.5 kilometres. In the Mount Dillworth area (Fig. 115) the 100-metre-thick exposure is divided by a hematitic siltstone band, parallel to the borders of the flow, suggesting subaerial weathering between two flows. Texturally, these distinctive flows are identical to dykes of Premier porphyry, which cut the underlying andesites, siltstones, and Texas Creek granodiorite (Fig. 116).

Dupas (this volume) describes an augite-porphyritic andesite flow (1f) in the Long Lake area. This rock type, which also lies at the top of the andesite sequence, may be a stratigraphic equivalent of the feldspar-porphyritic flows.

Sedimentary Rocks

Epiclastic Rocks [1e(Ep)]: Within the upper 2 000 metres of andesite tuffs (1e) are local lenses and pods of epiclastic, maroon to purple, siltstone, sandstone, and conglomerate. Epiclastic rocks represent quiescent periods when weathering and erosion took place during development of the andesitic volcano. These red units are distinctive and may be useful marker horizons on property scale.

Siltstone Members (1b, 1d): Two dark grey to black, thin-bedded siltstone members of regional extent provide stratigraphic and structural markers within the andesitic pile. The units strike north-northwest; they facilitate determination of bedding attitudes, stratigraphic tops, and fault offsets throughout the map-area.

The lower siltstone member (1b), the Mount Dolly member, lies mainly west of the map-area along most of the Salmon River valley. It forms a roof pendant in the Summit Lake granodiorite and reappears to the south at the Outland Silver Bar prospect (Fig. 115). The siltstone outcrops in the bed of the Salmon River at the north and south ends of Mineral Hill. In the Skookum (Mountain View) adit, the siltstone exposures are purple-brown, banded hornfels. At Mount Dolly this member is a thick sequence of east-trending thin-bedded, pyritic siltstone that forms the summit.

The upper siltstone member (1d), the August Mountain member, can be traced southward from the Haida claim (Portland prospect) to the crest of Bear River Ridge (Fig. 115). Midway between Mount Welker and Mount Dolly, the No. 5 International Boundary marker peg is cemented into these siltstones. Further southeast this unit may be the purple-brown hornfelsed, calc-silicate-veined siltstone that hosts minor amounts of sulphide mineralization in the Molly B and Red Reef adits on Mount Rainey. The upper siltstone also hosts precious metal veins at the East Gold mine. Weathering of local pyrite alteration in the siltstones produced the brightly coloured, gossanous exposures that crop out from north of the East Gold mine southward to the Millsite fault. The unit provides evidence for major offsets along the Millsite fault, the Morris Summit fault, and the Slate Mountain fault.

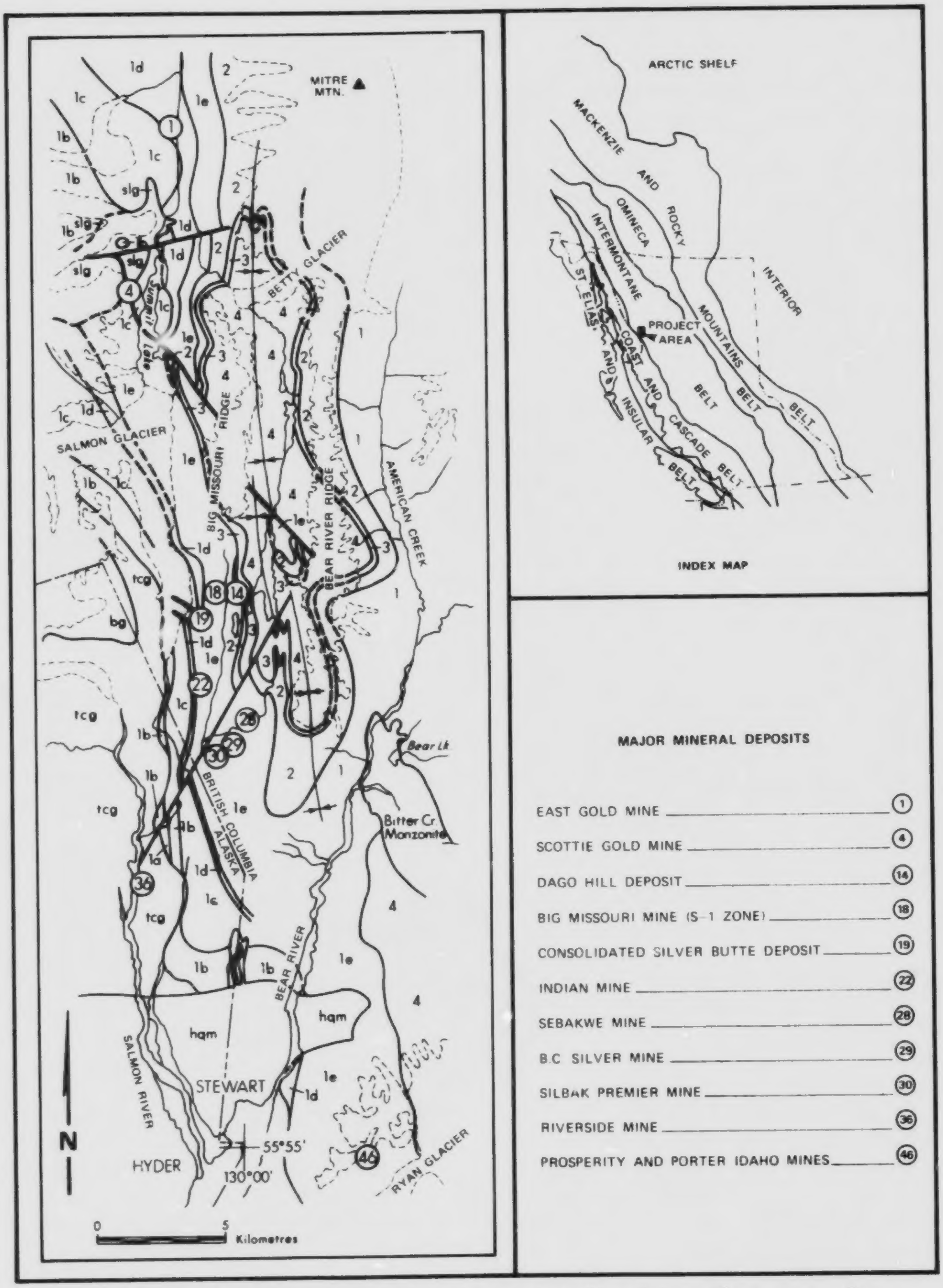

MITRE MTN.
BETTY GLACIER
SALMON GLACIER
BIG MISSOURI RIDGE
BEAR RIVER RIDGE
AMERICAN CREEK
Bear Lk
Bitter Cr. Monzonite
BRITISH COLUMBIA
ALASKA
BEAR RIVER
SALMON RIVER
STEWART
HYDER
55°55'
130°00'
RYAN GLACIER
N
0
5
Kilometres
ARCTIC SHELF
MACKENZIE AND ROCKY MOUNTAINS BELT
OMINECA BELT
INTERMONTANE BELT
INTERIOR
PROJECT AREA
COAST AND CASCADE BELT
ST ELIAS AND INSULAR BELT
INDEX MAP
MAJOR MINERAL DEPOSITS
EAST GOLD MINE ①
SCOTTIE GOLD MINE ④
DAGO HILL DEPOSIT ⑭
BIG MISSOURI MINE (S-1 ZONE) ⑱
CONSOLIDATED SILVER BUTTE DEPOSIT ⑲
INDIAN MINE ㉒
SEBAKWE MINE ㉘
B.C SILVER MINE ㉙
SILBAK PREMIER MINE ㉚
RIVERSIDE MINE ㊱
PROSPERITY AND PORTER IDAHO MINES ㊻

Figure 115. Geology and major mineral deposits, Salmon River area. See Tables 1A and 1B for lithologic symbols.

TABLE 1A
TABLE OF FORMATIONS

UNIT SYMBOL	NAME AND LITHOLOGY	THICKNESS (metres)
4-SS	SEDIMENTARY SEQUENCE	
4b-SS	Sedimentary sequence: carbonaceous and calcareous sedimentary rocks; argillite, siltstone, slate, sandstone, conglomerate, lesser limestone	>300
4a-TZS	Transition zone sedimentary rocks: black grits, sandstone, argillite, limestone, fossiliferous limestone, pumice conglomerates, weakly pyritic facies with upper Middle Jurassic-Bajocian to Callovian fossils	4-10
3-FVS	FELSIC VOLCANIC SEQUENCE	20-120
3f-BT	Black tuff: carbonaceous and lithic lapilli air fall tuff with interbedded sedimentary rocks	0-80
3e-PFT	Pyritic felsic tuff: siliceous air fall lapilli tuff and tuff breccia with 5 to 15 per cent disseminated pyrite	0-8
3d-UFT	Upper felsic tuff: siliceous, massive air fall lapilli tuff, and tuff breccia; partially welded	5-20
3c-MFT	Middle felsic tuff: felsic ash flows, single and compound units	10-40
3b-LFT	Lower felsic tuff: felsic, aphanitic, air fall dust tuff	5-15
3a-BF	Basal pumice facies: erosional remnants of air fall pumiceous tuff	0-16
2-ES	EPICLASTIC SEQUENCE	4-1 200
2b-EF	Epiclastic facies: conglomerate, sandstone, siltstone, lesser limestone	4-600
2a-DF	Dacitic volcanic facies: tuffs, crystal tuffs, lapilli tuffs, porphyritic flows	0-600
1-AS	ANDESITIC SEQUENCE	
1g-PPF	Premier porphyry flows: bimodal feldspar porphyritic andesite	0-60
1f-PPF	Augite porphyry flows: augite porphyritic andesite	0-60
1e-UAT	Upper andesite tuffs: dust tuffs, ash tuffs, crystal tuffs, lapilli tuffs, tuff breccias; interbedded epiclastic sedimentary rocks	2 000
1d-USM	Upper siltstone member: argillite, siltstone, sandstone, limestone, conglomerate	15-150
1e-MAT	Middle andesite tuffs: dust tuffs, ash tuffs, lapilli tuffs	1 750
1b-LSM	Lower siltstone member: argillite, siltstone, sandstone	50-200+
1a-LAT	Lower andesite tuffs: ash tuffs	100+

TABLE 18
TABLE OF INTRUSIVE ROCKS

UNIT SYMBOL	NAME AND LITHOLOGY	AGE (Ma)
tcg	Texas Creek granodiorite: hornblende, granodiorite, coarse grained, local coarse feldspar porphyritic phases	210
pp	Premier porphyry dykes: bimodal feldspar porphyritic diorite/andesite, ± hornblende, ± quartz phenocrysts	(?) Lower Jurassic
slg	Summit Lake granodiorite: hornblende granodiorite; medium to coarse grained	(?) Same as tcg?
mp	Mill porphyry dykes: bimodal feldspar-porphyritic diorite/andesite	(?) Same as pp?
bg	Boundary granodiorite: biotite granodiorite, golden sphene, ± hornblende; medium grained	52
hqm	Hyder quartz monzonite: biotite granodiorite to quartz monzonite, golden sphene, ± hornblende	50
pc	Portland Canal dyke swarm: early granodiorite, middle microdiorite, late lamprophyre	(?) Same as hqm?

MAP UNIT 2 - EPICLASTIC SEQUENCE (ES)

The epiclastic sequence comprises sedimentary rocks and interbedded dacitic tuffs and flows. The formation, which varies in thickness from 4 to 1 200 metres within the map-area, is interpreted to be a subaerial accumulation of reworked debris and onlapping dacitic volcanic flows that overlie the slopes of an andesitic stratovolcano.

Sedimentary Rocks (2b)

The sedimentary facies consists of conglomerates, sandstones, and siltstones. The hematized sedimentary rocks are generally purple to bright maroon coloured, but local greenish and mottled purple and green units occur within the sequence. The environment of deposition was predominantly subaerial and the conglomerate units may represent debris flows. A small, white limestone lens, 250 metres long by 6 metres thick, that outcrops on the southwest slope of Mitre Mountain is evidence of local lacustrine or marine conditions.

Monolithic epiclastic conglomerate beds coincide with areas in which the epiclastic formation is thin. These locations, on Mount Dillworth (Fig. 118) and at the north end of Long Lake (Dupas, this volume), are interpreted to be paleotopographic highs. The textures of the conglomerate cobbles are identical to those of the underlying andesitic rocks. Hematitic zones underlying these conglomerates may be lithified regoliths developed on the underlying andesitic strata.

Dacitic Volcanic Rocks (2a)

Dacitic dust tuff, crystal tuff, lapilli tuff, and porphyritic flows are interbedded within the epiclastic sequence. The dacites are of local extent because some sections through the epiclastic formation have no interbedded dacitic rocks. On Mount Rainey, however, the andesite formation of map unit 1 is capped by a thick sequence of dacitic volcanic rocks and there are no interbedded sedimentary rocks (Fig. 116). Therefore the dacite flows and tuffs may be onlapping units extruded from other nearby volcanic centres.

MAP UNIT 3 - FELSIC VOLCANIC SEQUENCE (FVS)

The felsic volcanic sequence provides an important regional marker. The rocks are mainly dense, resistant, variably welded tuffs. They display distinct lateral facies variations and compositional changes that can be related to paleotopography and depositional environment.

Basal Pumice Facies (3a)

On the northwest slope of Mount Dillworth, a narrow zone of massive pumiceous tuff is sandwiched between the andesitic sequence (unit 1) and the lower felsic tuff (3b; Fig. 116). The exposed pumice zone, which is 16 metres thick and 12 metres wide, consists of purple, massive, fine pumiceous ash with scattered rounded pumice lapilli up to 3 centimetres in diameter; the rock has local light grey lenses. The pumice must have been deposited near the vent area then rapidly eroded. Only remnants were preserved, such as this exposure apparently deposited in a deep stream channel or trough that was eroded through the unlithified epiclastic sediments to andesitic bedrock.

Lower Felsic Tuff (3b)

The lower member of the felsic volcanic sequence is a massive aphanitic dust tuff composed of volcanic dust and fine lithic particles. The rock is typically pale olive-grey to grey, but bright turquoise-coloured zones occur near Summit and Divide Lakes. Hematitic purple and bright maroon alteration zones give the rock a swirled or marbled pattern. The unit has sharp, conformable contacts with adjacent units.

At the southeast corner of Summit Lake (Fig. 115) the dust tuff contains fine, silica-filled vesicles and large euhedral pyrite crystals up to 1 centimetre in diameter.

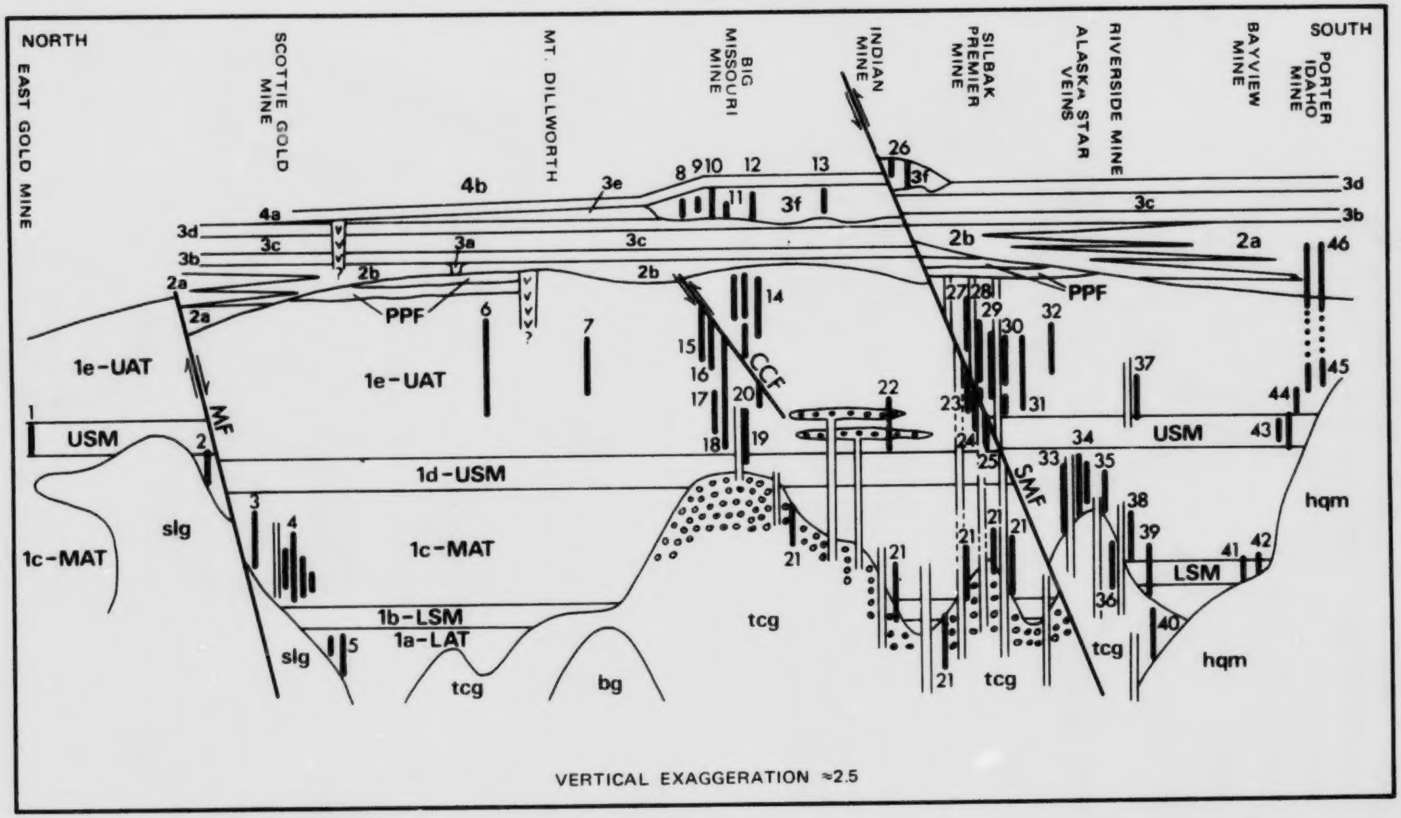

NORTH
EAST GOLD MINE
SCOTTIE GOLD MINE
MT. DILLWORTH
BIG MISSOURI MINE
INDIAN MINE
SILBAK PREMIER MINE
ALASKA STAR VEINS
RIVERSIDE MINE
BAYVIEW MINE
PORTER IDAHO MINE
SOUTH
4a
4b
3a
3b
3c
3d
3e
3f
2a
2b
PPF
MF
CCF
SMF
1e-UAT
USM
1d-USM
1c-MAT
1b-LSM
1a-LAT
LSM
slg
tcg
bg
hqm
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
VERTICAL EXAGGERATION ≈2.5

Figure 116. Schematic cross-section showing stratigraphic position of mineral deposits, Salmon River valley. See Table 1 and Figure 115 for legend.

LEGEND

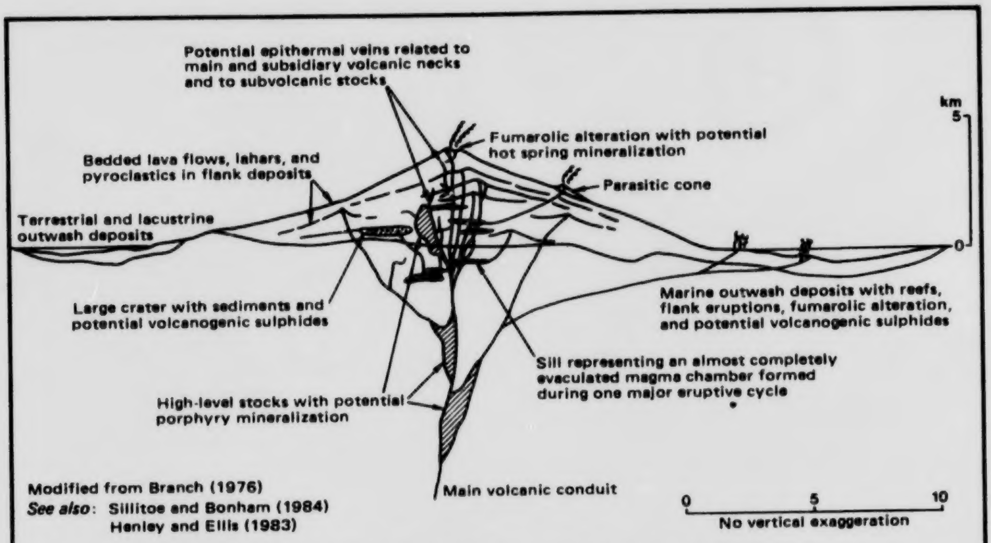
6▮ ▮7	VEIN DEPOSIT
M	VENT FACIES
▯	PREMIER PORPHYRY DYKE OR VOLCANIC NECK
⬭	SILL OF POPRHYRITIC TEXAS CREEK GRANODIORITE
▨	PORPHYRITIC BORDER PHASE OF TEXAS CREEK GRANODIORITE

SYMBOLS

FAULT	▬
MILLSITE FAULT	MF
MORRIS SUMMIT FAULT/ MINERAL GULCH FAULT	MSF
SPIDER FAULT	SF
CASCADE CREEK FAULT	CCF
SLATE MOUNTAIN FAULT	SMF
SYNCLINE AXIS	—┼—

KEY TO MINERAL DEPOSITS

1 EAST GOLD MINE
2 BEND VEIN (PYRRHOTITE)
3 SCOTTIE NORTH PROSPECT (PYRRHOTITE–PYRITE)
4 SCOTTIE GOLD MINE (O, M, N, L ZONES)
5 HICKS' VEINS (PYRRHOTITE)
6 49 PROSPECT
7 MARTHA ELLEN ZONE
8 LION GROUP (SILVER HILL)
9 SILVER CREST
10 SILVER TIP MINE
11 H VEIN
12 VEINS 400 METRES NORTHEAST OF BIG MISSOURI POWERHOUSE
13 VEINS ON WEST SLOPE OF SLATE MOUNTAIN
14 DAGO HILL PROSPECT (SEVERAL VEINS)
15 UNICORN NO. 1 (INCLUDES GOOD HOPE)
16 A VEIN
17 PROVINCE ZONE
18 BIG MISSOURI MINE (S-1 ZONE)
19 CONSOLIDATED SILVER BUTTE PROSPECT
20 TERMINUS PROSPECT
21 MASSIVE PYRRHOTITE VEINS ALONG FLOOR OF SALMON RIVER
22 INDIAN MINE
23 HOPE PROSPECT (GRANDUC ROAD SHOWING)
24 PREMIER EXTENSION
25 WOODBINE
26 LAKESHORE WORKINGS, SOUTH OF MONITOR LAKE
27 BUSH WORKINGS
28 SEBAKWE WORKINGS
29 B.C. SILVER WORKINGS
30 PREMIER WORKINGS
31 PREMIER BORDER WORKINGS
SILBAK PREMIER MINE
32 PICTOU WORKINGS
33 UNNAMED PYRRHOTITE VEIN
34 UNNAMED PYRRHOTITE VEIN
35 SCHAFT CREEK COPPER VEIN (PYRRHOTITE)
36 RIVERSIDE MINE
37 TITAN PROSPECT
38 UNNAMED PYRRHOTITE VEIN
39 ROANAN COPPER VEIN (PYRRHOTITE)
40 VEINS IN SKOOKUM/MOUNTAINVIEW ADIT
41 UPPER BAYVIEW VEINS
42 LOWER BAYVIEW VEINS
43 MOLLY B AND RED REEF VEINS
44 ORAL M VEIN
45 SILVERADO MINE
46 PROSPERITY/PORTER IDAHO MINES


Potential epithermal veins related to main and subsidiary volcanic necks and to subvolcanic stocks
Fumarolic alteration with potential hot spring mineralization
Bedded lava flows, lahars, and pyroclastics in flank deposits
Parasitic cone
Terrestrial and lacustrine outwash deposits
km
5
0
Large crater with sediments and potential volcanogenic sulphides
Marine outwash deposits with reefs, flank eruptions, fumarolic alteration, and potential volcanogenic sulphides
Sill representing an almost completely evaculated magma chamber formed during one major eruptive cycle
High-level stocks with potential porphyry mineralization
Main volcanic conduit
0
5
10
No vertical exaggeration

Modified from Branch (1976)
See also: Sillitoe and Bonham (1984)
Henley and Ellis (1983)

Figure 117a: Idealized model of ore deposit types related to an andesitic stratovolcano.

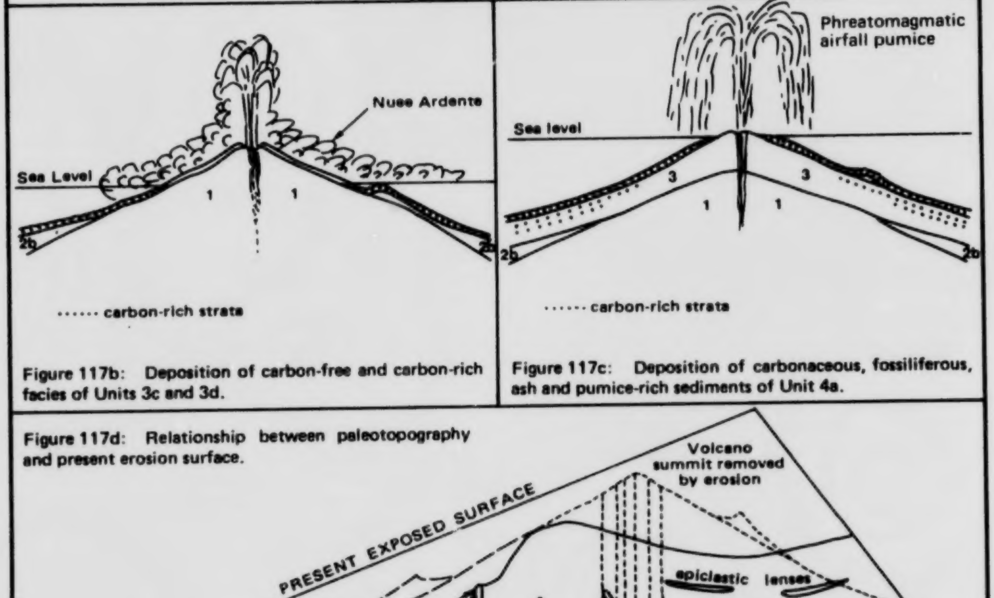

Nuee Ardente
Sea Level
1
1
2b
2b
...... carbon-rich strata
Phreatomagmatic airfall pumice
Sea level
3
3
1
1
2b
2b
...... carbon-rich strata

Figure 117b: Deposition of carbon-free and carbon-rich facies of Units 3c and 3d.

Figure 117c: Deposition of carbonaceous, fossiliferous, ash and pumice-rich sediments of Unit 4a.

Figure 117d: Relationship between paleotopography and present erosion surface.

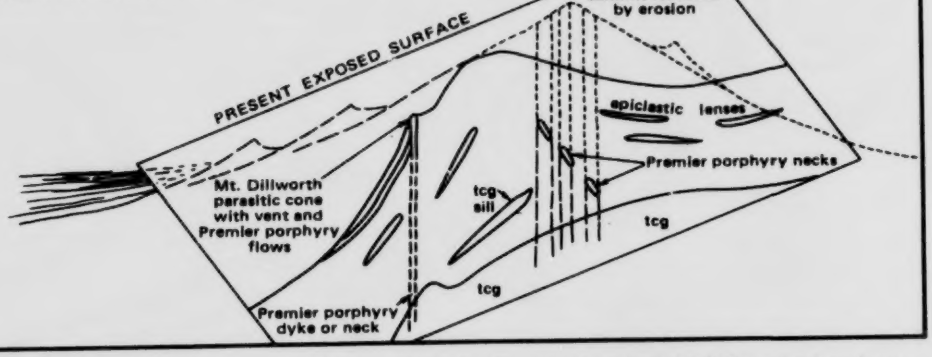

Volcano summit removed by erosion
PRESENT EXPOSED SURFACE
epiclastic lenses
Premier porphyry necks
Mt. Dillworth parasitic cone with vent and Premier porphyry flows
tcg sill
tcg
tcg
Premier porphyry dyke or neck

Figure 117. Metallogeny, evolution, and paleotopography of andesitic stratovolcano.

Middle Felsic Tuff (3c)

Variably welded ash flow tuff comprises the middle member of this felsic volcanic sequence. In the Mount Dillworth to Monitor Lake area (Fig. 115) sections of this member contain mixed fiamme and angular felsic lapilli and are overlain by pumice lapilli. Well-exposed sections show progressive welding down section; equidimensional pumice give way to black glassy fiamme. Outside the Mount Dillworth area subrounded pumice lapilli are abundant but the rocks are not welded.

Upper Felsic Tuff (3d)

The upper member of the felsic volcanic sequence is a siliceous lapilli tuff to tuff breccia that extends throughout the map-area. The unit may be partially welded but contains neither pumice fragments nor fiamme. Along much of its strike length the matrix of the unit is medium to dark grey (Fig. 117 b and c).

Pyritic Felsic Tuff (3e)

A pyritic, felsic lapilli tuff to tuff breccia trends along the west side of Mount Dillworth and along the east side of Summit Lake (Fig. 115). This unit ends sharply in a cliff at the south end of Mount Dillworth but progressively thins northward, finally wedging out along the west side of Troy Ridge (Fig. 116). Fragment size decreases progressively northward, from rounded 0.5-metre boulders to cobbles, then lapilli. The upper and lower contacts of this unit are sharp but irregular.

Cylindrical fumarolic pipes, 2 centimetres by 30 centimetres, oriented perpendicular to bedding in the pyritic tuff, are exposed along the top of a cliff at the soucheast corner of Summit Lake. These pipes are lined with encrustations of fine to medium-grained pyrite.

This unit is interpreted to be air fall lapilli tuff to tuff breccia that was deposited in a shallow, sulphur-rich, reducing marine environment. Fragment size variations indicate the source area of this unit is at the south end of Mount Dillworth (Fig. 116).

Black Tuff (3f)

The black tuff member is a thick unit of carbonaceous crystal and lithic lapilli tuffs with local argillaceous siltstone lenses. The lapilli consist of crowded porphyry flows or crystal tuffs, limestone, and rare pumice.

This member forms the uppermost unit of the felsic volcanic package. It extends from the south end of Mount Dillworth southward to the crest of Slate Mountain and is also exposed in a few outcrops south and south-southeast of Monitor Lake (Fig. 115). This rock type is well displayed in the dumps at the south end of the penstock tunnel near the Long Lake dam and in abandoned drill core near the Lakeshore workings south of Monitor Lake (Fig. 115). The black tuff overlies the upper felsic tuff (3d) and is stratigraphically equivalent to the pyritic lapilli tuff (3e). The contact relationships between the black tuff and the pyritic tuff are unknown. Both units host sulphide mineralization; thus they may be important keys to metallogenic interpretation of deposits in the underlying volcanic pile.

Two possible interpretations explain the limited strike extent of this distinctive, thick black tuff unit: (1) it may represent an erosional remnant of an originally extensive unit or (2) deposition was restricted to the area it now occupies. The latter interpretation indicates that the tuff was deposited in topographic low, such as a volcanic crater or a caldera.

MAP UNIT 4 - SEDIMENTARY SEQUENCE (SS)

Transition Zone Sedimentary Rocks (4a)

The transition zone sedimentary rocks were originally considered as a separate unit (Alldrick, 1984), but, on the basis of preliminary fossil examination, are now interpreted to be the basal unit of the main sedimentary sequence. The best exposures of this unit are seen at the cliff top near the southeast corner of Summit Lake, north of the 49 Ridge, and on the crest of Slate Mountain (Fig. 115).

The basal member consists of dark grey to black grits, ash-rich argillaceous siltstones, and local lenses and thin beds of fossiliferous limestone and conglomerate. These sedimentary rocks contain local horizons with sparsely disseminated pyrite. Thin conglomerate layers at Summit Lake and on Slate Mountain contain rounded pebbles of pumice. H. W. Tipper (personal communication, 1984) has identified pectin-like bivalves from the fossil-rich limestones of this unit to be of Bajocian to Callovian (upper Middle Jurassic) age.

The basal member lies disconformably on volcanic lapilli tuffs of the pyritic felsic and black tuff units (3e and 3f). Its upper contact is marked by a regional bedding plane fault that separates this unit from the overlying main sedimentary sequence (Alldrick, 1984, Figs. 58 and 60).

Sedimentary Sequence (4b)

The main sedimentary sequence, which is well exposed on the east side of Mineral Gulch, southeast of Summit Lake, is described by Grove (1971) and Alldrick (1984). The lower 100 metres of this formation comprise black, thin to medium-bedded argillites, calcareous siltstones, and shales with minor intercalations of light grey limestone, and cherty beds that may be tuffaceous. Above these are medium grey greywackes, sandstones, and intraformational conglomerates. Trace amounts of disseminated pyrite outline some bedding planes within the siltstones.

The upper contact of the main sedimentary sequence was not observed in the study area; the lower contact is marked by a 5 to 30-metre-thick zone of intense deformation and quartz veining adjacent to the bedding plane fault.

INTRUSIVE ROCKS

TEXAS CREEK GRANODIORITE

The Texas Creek granodiorite is a distinctive coarse-grained hornblende granodiorite that has been studied by Buddington (1929), Grove (1971, 1973), and Smith (1977). Buddington (1929, p. 22) first noted the spatial relationship between the Texas Creek stock and mineral deposits in the Salmon River valley and suggested a genetic link.

Core Phase

The core of the main intrusive is a massive, equigranular, medium to coarse-grained hornblende granodiorite, with up to 15 per cent coarse, euhedral hornblende. This hornblende-rich, coarse-grained texture is a characteristic feature of the Texas Creek granodiorite that can be recognized through all alteration and deformation.

Border Phase

Along the Salmon River, the Big Missouri Ridge and the Bear River Ridge (Fig. 115), the eastern margin of the stock comprises coarse-grained feldspar-porphyritic hornblende granodiorite; this zone is several hundred metres wide. The phenocrysts in the border phase are 1 to 4-centimetre euhedral orthoclase crystals similar to phenocrysts in the Premier porphyry dykes and flows. Prismatic hornblende and orthoclase crystals display a subtle preferred orientation in some samples.

Characteristically, the margins of the Texas Creek granodiorite contain a narrow zone, up to a few tens of metres wide, of medium to dark greenish grey chloritic alteration that is sometimes accompanied by fractures and a crude foliation. Shearing and broken grains suggest that this narrow zone results from crushing along the contact of the granodiorite.

Sill Phase

P. McGuigan and G. Dawson (personal communication, 1984) have identified two sill-like feldspar-porphyritic lenses of Texas Creek granodiorite at

TABLE 2
WHOLE ROCK AND TRACE ELEMENT ANALYSES

	27622[1]	27623[2]	27624[3]	27625[4]	27626[5]	27627[6]	27628[7]	27629[8]	27630[9]	27631[10]	27632[11]	27633[12]	27634[13]
SiO_2	49.24	61.31	57.54	65.34	65.87	61.43	59.17	38.50	53.09	57.49	53.31	66.12	60.01
Al_2O_3	24.83	18.23	14.47	16.22	12.27	13.82	14.13	5.63	14.19	15.31	14.02	13.51	16.10
Fe_2O_3	12.47	7.24	4.86	5.28	11.53	9.48	9.62	1.52	8.33	6.58	4.54	7.68	8.32
MgO	1.84	2.46	1.65	1.80	3.18	1.61	0.72	0.52	5.94	2.80	0.59	0.56	3.34
CaO	0.13	2.14	7.34	4.37	1.03	3.70	2.06	28.46	4.98	4.34	9.68	<0.03	0.38
Na_2O	1.82	2.13	0.24	3.45	0.52	4.16	3.69	1.47	2.45	3.43	4.59	0.03	0.81
K_2O	4.33	3.12	4.74	2.05	0.92	0.48	2.10	1.01	2.93	3.19	1.52	4.45	3.77
TiO_2	1.24	0.77	0.52	0.48	1.11	0.97	1.19	0.35	0.64	1.39	1.16	1.26	0.63
MnO	0.106	0.107	0.270	0.099	0.060	0.101	0.049	0.119	0.210	0.130	0.152	<0.004	0.062
FeO	2.64	5.18	2.08	1.24	7.09	7.66	2.23	0.57	6.99	4.69	1.72	1.20	4.23
S	0.01	0.01	1.39	<0.01	0.01	<0.01	5.40	0.7	0.28	0.04	2.19	5.17	0.35
FeS_2							10.1				1.91	4.5	
CO_2	<0.07	0.14	5.31	0.21	0.49	2.81	1.26	22.11	3.87	2.83	7.32	1.04	1.87
H_2O-	0.71	0.32	0.31	0.29	0.33	0.36	0.42	0.22	0.22	0.24	0.25	0.25	0.96
H_2O+	4.39	3.17	2.82	2.07	3.60	2.84	1.36	1.30	3.35	2.47	1.53	2.01	3.59
L.O.I.	3.7	3.0	3.1	2.1	5.0	5.0	6.7	22.3	6.9	4.8	9.3	6.0	5.5
Ni	13	2	<2	2	<2	4	<2	17	38	14	5	5	5
Cr	14	3	3	3	2	8	7	22	38	15	5	4	25
Ba	0.21	0.21	0.3	0.21	0.09	0.05	0.15	0.13	0.23	0.23	0.10	0.16	0.23
Sr	0.04	0.04	0.02	0.02	0.03	0.03	0.03	0.05	0.02	0.04	0.03	7.0 ppm	37 ppm
P	<0.04	0.13	0.1	0.15	N.D.	0.2	0.28	0.19	0.15	0.25	0.25	N.D.	0.31

[1] Maroon epiclastic siltstone (map unit 2). Northeast of Big Missouri powerhouse.

[2] Felsic lapilli tuff (map unit 2). East and uphill of Silbak Premier mine.

[3] Premier Porphyry dyke. Granduc road. Road cut north of Silbak Premier mine.

[4] Purple epiclastic pebble conglomerate, heterolithic (map unit 2). Crest of Bear River Ridge, east of Silbak Premier mine.

[5] Maroon dust tuff (map unit 3b). Northeast of Monitor Lake.

[6] Cream-coloured felsic tuff; massive, aphanitic. Base of map unit 2c. East of Monitor Lake.

[7] Pyritic felsic tuff breccia (map unit 3a). South end of Mount Dillworth.

[8] Carbonaceous, calcareous grit (map unit 4a). South end of Mount Dillworth.

[9] Black, carbonaceous, massive fine-grained ash tuff (map unit 1). In hangingwall of upper siltstone member. Granduc road 10.5-mile marker.

[10] Leucocratic felsic tuff or flow, massive (map unit 1). South of Indian Lake.

[11] Pyritic felsic lapilli tuff (map unit 3a). North end of Mount Dillworth.

[12] Dark grey pyritic pumice lapilli tuff (top of map unit 3c). Between Harris Creek and Mount Dillworth.

[13] Black, carbonaceous, lapilli tuff (map unit 1). In hangingwall of upper siltstone member. North of Consolidated Silver Butte prospect.

Note: Recalculation of S values as FeS_2 yields points 7', 11', and 12' on Figure 118.

the Indian mine. These north-trending sills dip 70 degrees east, parallel to bedding in nearby outcrops of the upper siltstone member. Branch (1976) suggests that such coarse-grained, subvolcanic sills may represent evacuated and collapsed magma chambers from early eruptive cycles (Fig. 117a).

The sills consist of large orthoclase phenocrysts in a medium to coarse-grained hornblende granodiorite matrix. This matrix texture, the higher hornblende content, and the absence of chloritic alteration, distinguish Texas Creek granodiorite from the finer grained, hornblende-poor chloritic matrix of dykes and flows of Premier porphyry.

PREMIER PORPHYRY

Typical Premier porphyry dykes are medium to dark green porphyritic rocks composed of large (1 to 4-centimetre) orthoclase phenocrysts and smaller (0.5-centimetre) plagioclase phenocrysts in a fine-grained crystalline matrix. Samples also commonly contain euhedral hornblende phenocrysts up to 1 centimetre long, and scattered quartz eyes that make up to 4 per cent of the rock by volume. A whole rock analysis of a Premier porphyry dyke plots within the overlapping andesite-dacite field (Fig. 118).

These dykes cut the margins of the Texas Creek granodiorite and all the rocks within the andesite sequence. Within the Texas Creek granodiorite, the dyke matrix is medium grained and less chloritic. One 3-metre-wide dyke exposed in the bed of the Salmon River shows dark, 6-centimetre-thick chilled margins along both edges. These dykes were discussed by Buddington (1929) and Grove (1971) who interpreted them as a contemporaneous peripheral dyke phase of the main Texas Creek stock. Published maps by Grove (1971, Fig. 3; 1983) include the Premier porphyry dykes as part of the main granodiorite mass, therefore his contact is highly irregular and extends well east of the actual contact of the main Texas Creek pluton, which is relatively regular. The Premier porphyry dykes are generally interpreted to form tabular sheets; however, at Silbak Premier mine they form elliptical pipes, plugs, or volcanic necks. At Silbak, the elliptical pipes have an east-southeast-trending long axis and plunge 60 degrees toward the west-northwest. The many ore deposits of the Silbak Premier mine occur as crescent-shaped vein networks and breccia zones along the contacts of these plugs.

The Premier porphyry dykes are not restricted to the area of the Silbak Premier mine; they occur as far south as the Riverside mine and as far north as the toe of the Salmon Glacier (Fig. 115). The 'Mill porphyry' dyke at the lower portal of Scottie Gold mine is texturally identical to other Premier porphyry dykes, but is light grey and lacks the characteristic pervasive chloritic alteration.

Porphyritic volcanic flows with bimodal feldspars are present at the top of the andesitic volcanic sequence near the Silbak Premier mine, along

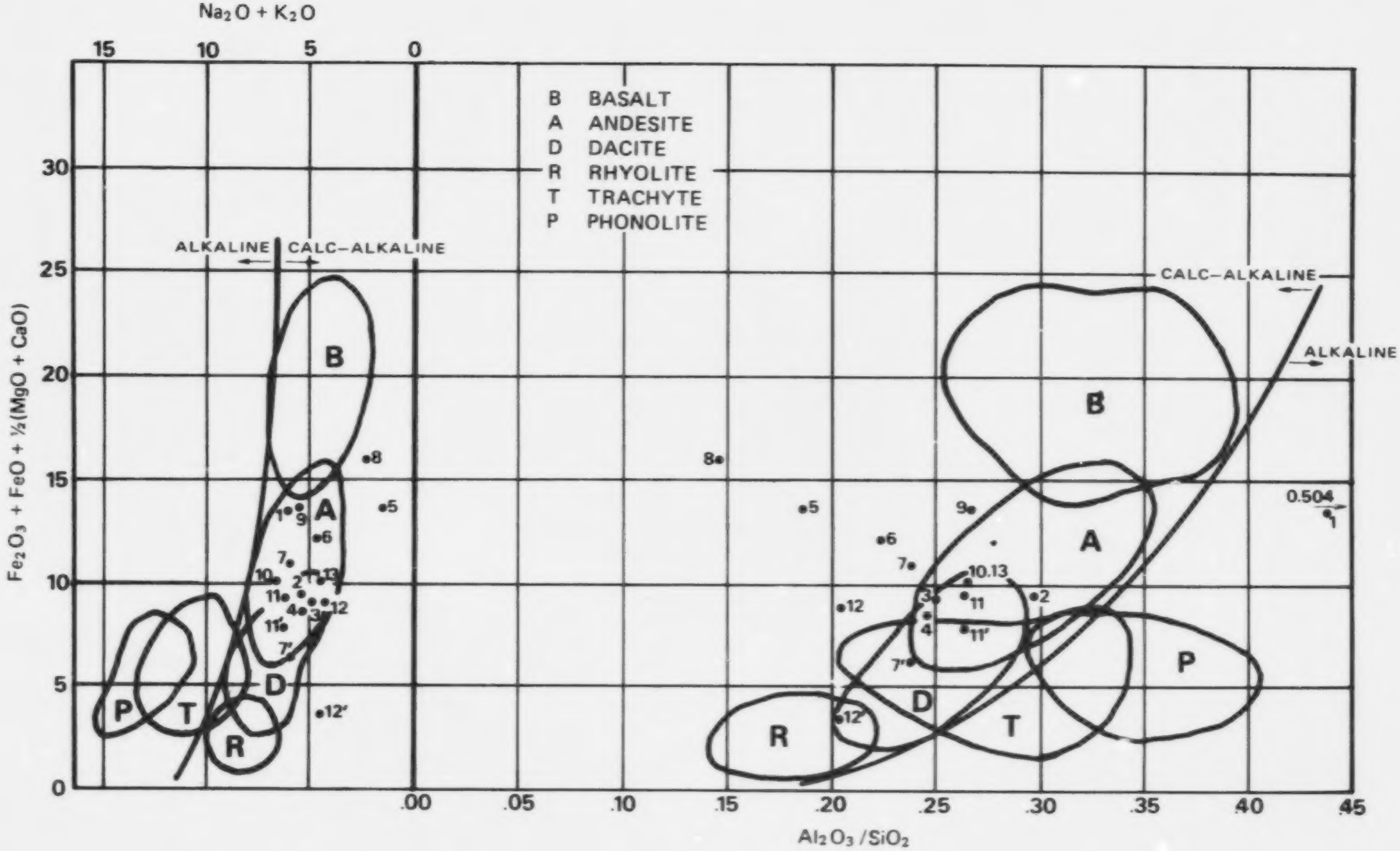


Figure 118. Compositions of 16 volcanic and volcaniclastic rocks analysed from Salmon River area (results are listed in Table 2).

the west side of Mount Dillworth and in the bed of Summit Lake (Fig. 116). The Premier porphyry dykes are interpreted to have fed these flows and are considered to be a late magmatic phase of the main Texas Creek granodiorite pluton.

It should be noted that the 'Premier porphyry' dykes are not the same rocks as the 'Premier dyke swarm,' which was discussed in some early reports. The Premier dyke swarm consists of subparallel granodiorite, diorite, and lamprophyre dykes of probable Tertiary age.

SUMMIT LAKE GRANODIORITE

The Summit Lake stock, also termed the Berendon granodiorite, was described by Grove (1971, 1973). The rock is a medium to coarse-grained hornblende granodiorite with minor amounts of fine biotite. The stock is elongated east-northeast, partly because of 1 200 metres of right lateral offset along the Millsite fault (Alldrick, 1984, Fig. 59). Roof pendants of country rock in the stock outcrop along the cliff top on the south side of Berendon Glacier, 1 kilometre west of the Granduc millsite (Fig. 115).

Grove (1973) concluded that although the Summit Lake granodiorite was probably Tertiary, it could be an outlier of the Mesozoic Texas Creek granodiorite. The Summit Lake and the Texas Creek granodiorites have several similarities: both are hornblende granodiorites, both have spatially associated Premier porphyry (Mill porphyry) dykes, both predate Tertiary dyke swarms, and both have peripheral gold-bearing massive pyrrhotite veins; none of these features occur at other stocks in the region. They also have significant differences: the Texas Creek granodiorite has both a distinctive orthoclase-porphyritic border phase and a sheared, chloritized margin - the Summit Lake stock does not; the Summit Lake stock has an extensive aureole of hornfelsed, silicified, and pyritized country rock - the Texas Creek stock does not. Despite the differences, field evidence suggests that the Summit Lake and Texas Creek granodiorites are correlative.

HYDER QUARTZ MONZONITE

The Hyder stock ranges in composition from quartz monzonite to granodiorite (Buddington, 1929; Grove, 1971, 1973; Smith, 1977). The rock is predominantly coarse-grained biotite granodiorite with minor amounts of hornblende; orthoclase is pink and slightly prophyritic, and fine-grained golden sphene crystals are characteristic.

The Hyder pluton is spatially related to silver-rich galena-sphalerite-freibergite veins of the Prosperity/Porter Idaho mine (Alldrick and Kenyon, 1984), the Silverado mine (White, 1946), and the Bayview mine (Fig. 116).

White to cream aplite dykes described by Buddington (1929, pp. 28, 29), which crop out around the periphery of the Hyder stock, are probably genetically related to it. In two exposures along Skookum Creek these dykes contain scattered knots, up to 2 centimetres diameter, of coarse molybdenite flakes. Molybdenite mineralization occurs within a few metres of a similar dyke in the Molly B adit.

Smith (1977; *see* Table 3) listed a biotite K/Ar age of 50 Ma for the stock. None of the major Tertiary dyke swarms in the region cuts the stock; therefore this age places a possible upper limit on the age of the dyke swarms.

TABLE 3
RECALCULATED K/Ar DATES

Data presented by Smith (1977) have been recalculated with the decay constants of Steiger and Jager (1977):

SAMPLE NO.	MINERAL	AGE (Ma)	UNIT AND LOCATION
68ASj-160	Hornblende Biotite	210.8±6 108.2±3	Texas Creek granodiorite. East side of Ferguson Glacier.
3S-008	Hornblende Biotite	202.3±6 130.4±3	Texas Creek granodiorite. 1.0 km north of toe of Ferguson Glacier.
68ASj-52	Biotite	50.4±2	Hyder quartz monzonite. Small road cut at International Boundary near Hyder.
68ADn-47	Biotite	47.3±1	Hyder quartz monzonite. East margin of Soulé Glacier.
68ADn-75	Hornblende Biotite	51.6±2 52.2±4	Boundary granodiorite. Boundary Glacier, near Border Monument 16.
8S-163	Hornblende Biotite	49.9±2 50.5±2	Boundary granodiorite. Nunatak in Chickamin Glacier, 400 m north of border.

BOUNDARY GRANODIORITE

The Boundary granodiorite, which straddles the Canada-United States border southwest of Salmon Glacier (Fig. 115), was not examined in this study. The texture, mineralogy, modal composition, and radiometric age of this granodiorite are identical to those of the granodiorite phase of the Hyder quartz monzonite (Smith, 1977).

LONG LAKE AUGITE PORPHYRY

The Long Lake 'stock' underlies the north end of Long Lake, 3 kilometres northeast of the Big Missouri mine (Fig. 115). In the literature this rock is described as an augite-porphyritic diorite intrusion (Schofield and Hanson, 1922, p. 25; Hanson, 1929, p. 12, 1935, p. 20; Grove, 1971, 1973, 1983). Mapping during the 1984 season showed that the rock unit predates and stratigraphically underlies epiclastic rocks of map unit 2. It displays no intrusive relationships (Dupas, this volume) and is more likely an extrusive rock. This unit is, therefore, interpreted to be an augite porphyritic andesite flow and the upper unit of the andesitic volcanic sequence (unit 1). Other augite-porphyritic rocks that have been mapped as intrusions in the area (Hanson, 1929, maps 215A, 216A; Grove, 1971, Figs. 3A, 3B) should be re-examined.

DYKES

Tertiary (?) Dyke Swarms

Rocks in the Salmon River valley are cut by three swarms of felsic to mafic dykes. The Portland Canal dyke swarm occupies the widest area and is the longest of the three swarms. Dykes in the swarm dip steeply southwest and trend east-southeast to southeast. The swarm goes past the south end of the Mount Dillworth snowfield, crosses the north end of Long Lake, and continues over Bear River Ridge at Mount Bunting (Fig. 115; Grove, 1971, Fig. 3).

Another narrower dyke swarm trends south along Tide Lake Flats, and across the upper portal area of Scottie Gold mine to August Mountain (Wares and Gewargis, 1982). At August Mountain the zone swings southeast (Grove, 1971, Fig. 3C) and continues over the crest of Mount Dillworth. Southeast of Mount Dillworth, toward Mount Bunting, this zone merges with the wider Portland Canal dyke swarm.

A third, major southeast-striking dyke swarm subparallels the international boundary near the Silbak Premier mine (Grove, 1971, Figs. 3A, 3B). This swarm was called the 'Mount Dolly dyke swarm' by Smith (1977) but the 'Premier dyke swarm' by Grove (1971). Both terms are misleading and are rejected; these dykes do not cross Mount Dolly, and a similar term, 'Premier porphyry dykes,' refers to an entirely different rock type. Here this dyke swarm is termed the 'Mount Welker dyke swarm' which indicates an area of excellent exposures of these dykes.

Each swarm contains three dyke lithologies. The oldest are massive, fine to medium-grained, light grey biotite or biotite-hornblende granodiorites that may be up to 60 metres in width. These are intruded by aphanitic, granular, greyish green microdiorite or 'andesite' dykes up to 10 metres in width. These in turn are cut by swarms of thin, dark brownish grey, variably porphyritic lamprophyres. These lamprophyre dykes rarely exceed 50 centimetres in width.

In the centre of these dyke swarms the intrusive rock comprises more than 50 per cent of the bedrock, only narrow lenses and slices of country rock separate the anastamosing dykes. Together, the three dyke swarms represent a northeasterly crustal extension of at least 1.5 kilometres. The three swams are probably of Tertiary age; they do not cut the 50 Ma old Hyder quartz monzonite stock and are probably contemporaneous with it.

Other Dyke Rocks

Other dykes in the Salmon River valley include buff, flow-banded aplite dykes that 'meander' through the country rock. Only four such dykes were noted, all along the west side of Mount Dillworth (Fig. 115).

Pale pink aplite dykes are common within the Hyder quartz monzonite stock. The surrounding country rock is cut by white to cream aplite dykes at the Skookum adit, at Silver Falls, and at the toe of Barney Glacier.

Premier porphyry dykes are reviewed under a separate heading in this report; additional information is given by Alldrick (1984).

PETROCHEMISTRY

Galley (1981, pp. 80-88) reports the results of 16 whole rock analyses from the Big Missouri mine area; an additional 13 whole rock analyses were completed as part of this study. These results are listed in Table 2 and plotted on Figure 118. Samples of hematitic epiclastic siltstone, hematitic dust tuff, and black carbonaceous grit were included in the sample suite to determine whether rocks derived from volcanic parent rocks are chemically distinctive.

As Galley found, most of the volcanic rocks show high potassium values relative to magnesium, calcium, and sodium. The variably textured tuffs of map unit 1 are of andesitic composition, while the more leucocratic, pumiceous tuffs and ash flow tuffs of map unit 3 are dacitic. The volcanic rocks are subalkaline and become slightly more calc-alkaline up section.

PALEOTOPOGRAPHY

Individual units within all four major stratigraphic sequences show distinct lateral facies changes that reflect the structure and paleotopography of this volcanic complex (Fig. 117). The accumulation of andesitic pyroclastic breccias along Mount Dillworth and the location of a volcanic vent or fissure at the top of the andesite section suggest that the 49 Ridge area on Mount Dillworth was a local paleotopographic high. The decrease in thickness of the overlying epiclastic rocks supports this interpretation and suggests a similar paleotopographic high at the north end of Long Lake.

The thickest section of felsic volcanic rocks is about 2 kilometres north of the 49 Ridge area. A narrow, 1.5-metre-wide fissure within the felsic volcanic rocks is exposed in the cliff at the southeast corner of Summit Lake. Incorporation of augite porphyritic andesite boulders in felsic volcanic strata at Long Lake indicates a felsic vent also broke through the andesitic pile in that area.

The upper part of the middle felsic tuff (3c) is variably impregnated with carbon suggesting either that it was deposited in a reducing, subaqueous environment or was inundated shortly afterward. No similar carbon impregnation of this unit occurs along Mount Dillworth or in the Summit Lake area, indicating that the unit was emegent there (Fig. 117b). Similarly, the overlying felsic lapilli tuff (3d) is carbon rich in many areas, but not along Mount Dillworth ridge.

Gradation of fragment size within the pyritic felsic tuff (3e) indicates a vent for this unit near the south end of Mount Dillworth. The disseminated pyrite may indicate fumarolic activity in either high water table or shallow marine conditions.

The black tuff (3f) represents accumulation of crystal and lithic lapilli tuff in subaqueous conditions in a volcanic crater, caldera, or lateral basin. The pumice conglomerate beds of unit 4a are evidence that the onset of sedimentation was contemporaneous with waning felsic volcanic activity (Fig. 117c).

AGE RELATIONSHIPS

Age dates for intrusive rocks of the Salmon River valley are shown in Table 1B. Smith's (1977) K/Ar dating results have been recalculated with revised decay constants (Steiger and Jager, 1977) and are listed in Table 3. Sedimentary rocks at the base of unit 4 have fossil suites of upper Middle Jurassic age (H. W. Tipper, personal cummunication, 1984; Grove, 1973).

The following field relationships indicate several sequential geologic events. The Texas Creek granodiorite stock intruded the lower 2 000 metres of the andesitic volcanic pile but not the upper 2 000 metres. The margins of the Texas Creek granodiorite and all units of the andesitic volcanic sequence are cut by Premier porphyry dykes but these dykes do not cut any of the epiclastic or younger rocks (units 2, 3, and 4). Extensive volcanic flows of Premier porphyry and augite porphyry mark the top of the andesite sequence. The andesitic volcanic sequence is overlain by epiclastic rocks (unit 2) which include boulders of Premier porphyry and augite porphyry. The epiclastic rocks are overlain by felsic volcanic tuffs and ash flow tuffs (unit 3) which in turn are overlain by a sedimentary sequence with a distinctive basal sedimentary facies (unit 4a). These basal sedimentary rocks include fossiliferous limestone lenses with upper Middle Jurassic fossils; thin beds with rounded pumice pebbles may represent contemporaneous felsic volcanism.

The following history fits field relationships and age dates together and is summarized in Table 4. The Texas Creek granodiorite pluton has a minimum K/Ar age of 210 Ma. Thus, the lower part of the andesitic volcanic sequence and perhaps the entire unit is probably of Late Triassic age or older. The Premier porphyry dykes and flows are probably

Early Jurassic in age (210 to 190 Ma), because they cut and overlie the andesite sequence. The Texas Creek stock is interpreted to be coeval and epizonal; it formed a subsidiary magma chamber in the andesitic stratavolcano, and was emplaced at a depth of about 2 kilometres (Williams and McBirney, 1979, p. 69; Gill, 1981, pp. 59-61). Thus the Texas Creek granodiorite is an integral part of the Mesozoic volcanic package and not part of the Coast Plutonic Complex, as suggested by Brew and Morrell (1983).

TABLE 4
GEOLOGIC HISTORY

Age (Ma)	Event
~50	Formation of argentiferous vein deposits and spatially associated MoS_2 and WO_3 deposits
50	Intrusion of Hyder quartz monzonite and Boundary granodiorite stocks
~50	Crustal extension and intrusion of major dyke swarms
?	Deformation, north-trending fold axes
~180	Marine transgression, onset of sedimentation (unit 4)
~180 ?	Formation of gold-silver vein deposits
~180	Felsic volcanism (unit 3); predominantly subaerial
190	Deposition of epiclastic sediments and interbedded dacitic tuffs and flows (unit 2)
~200	Emplacement of Premier porphyry dykes and flows
210	Intrusion of Texas Creek granodiorite and Summit Lake granodiorite stocks
230-200	Andesitic volcanic activity (unit 1); predominantly subaerial, with two periods of marine transgression

A period of subaerial weathering and erosion (190 to 180 Ma) was followed by an episode of felsic volcanism (180 Ma). This episode was probably short-lived because no intraformational sedimentary rocks are preserved within the felsic volcanic sequence. As felsic volcanism waned in Middle Jurassic time (180 Ma), transgressing seas covered even the highest topographic areas. Deposition of sedimentary strata began and continued until middle Late Jurassic time (180 to 150 Ma; Tipper and Richards, 1976).

Sedimentation was followed by moderate deformation with low grade metamorphism of sub-greenschist to lower greenschist facies, by intrusion of the major dyke swarms, and finally, by intrusion of the Hyder and Boundary stocks (50 Ma). These three events were nearly contemporaneous but their relative sequence can be seen in field relationships.

STRATIGRAPHIC DISTRIBUTION OF MINERAL DEPOSITS

An idealized cross-section (Fig. 116) shows the stratigraphic position of all major and some minor sulphide veins within the Salmon River valley. Six general relationships concerning deposit distribution are illustrated. These are listed here with deposit names and Mineral Inventory file numbers:

(1) The margins and peripheral country rock of the two hornblende granodiorite plutons are characterized by gold-bearing massive pyrrhotite veins with silver:gold ratios of less than or about 1:1. These include the Scottie Gold mine, 104B-34; Scottie North zone, 104B-74; Bend vein (Camp vein); Hicks veins; several pyrrhotite veins outcropping in the bed of the Salmon River between the toe of the glacier and the Daly-Alaska workings at the 18.5-mile marker on the Granduc road; and five veins on the Alaska Star property of Pulsar Energy and Resources Incorporated, that outcrop east and uphill of the Riverside mine.

(2) The 2 000-metre section of andesitic strata between the upper siltstone member (1d) and the epiclastic sequence (2) hosts many deposits of base and precious metal-rich sulphides; they occur in brecciated quartz-carbonate veins. The vein structures enclose fragments of wallrock, chalcedonic quartz, and sulphides. These veins have silver:gold ratios ranging from 500:1 to 2:1; most fall in the range 100:1 to 3:1. This deposit type includes those in the Big Missouri mine area, 104B-2, 104B-38, 104B-39, 104B-40, 104B-46, 104B-92, and 104B-93; the Consolidated Silver Butte prospect; the Silbak Premier mine, 104B-53, 104B-54; the Indian mine, 104B-31; the East Gold mine, 104B-33; and possibly several others such as Woodbine; Premier Extension, 104B-52; Pictou; Titan, 104B-71; Lila; Cassiar Rainbow; Outland Silver Bar, 104B-30; and the Portland prospect, 104B-82.

(3) Vuggy quartz-breccia veins are characteristic of the black tuff (3f). These contain fragments of chalcedonic quartz and host coarse galena-sphalerite-freibergite mineralization. Such veins have silver:gold ratios of 200:1 and higher. These deposits include those seen at Lakeshore, 104A-14; the Lion Group, 104B-41; Silver Crest, 104B-42; Silver Tip, 104B-43; Unicorn No. 3, 104B-44; Mineral Hill, 104B-45; H-Vein; and unnamed veins on the west slope of Slate Mountain, and on the ridge 400 metres east of the Big Missouri power plant.

(4) Along the western edge of the Mount Dillworth snowfield, felsic air fall lapilli tuff and tuff breccia of unit 3e contain 10 to 15 per cent finely disseminated pyrite over a thickness of as much as 8 metres. This stratabound pyritic zone is barren of base and precious metals; however, it may indicate potential for volcanogenic exhalative massive sulphide deposits at this stratigraphic position elsewhere in the Hazelton Group of central British Columbia (for example, Tom MacKay Lake, 104B-8).

(5) The massive galena-sphalerite-freibergite veins that occupy shears and faults around the margin of the Eocene Hyder quartz monzonite stock have silver:gold ratios greater than 1 000:1. Examples of this type are Prosperity/Porter Idaho mine, 103P-89; Silverado mine, 103P-88; Flat Vein; and Bayview mine, 103P-51.

(6) Structurally deeper levels around the perimeter of the Hyder stock are characterized by biotite hornfels alteration of siltstone horizons and by low-grade tungsten deposits with associated molybdenum, as seen at the Molly B adit, 103P-85; the Skookum/Mountainview adit, 103P-45; and the Riverside mine, 104B-73.

Mineral deposits that do not fit into this classification include: the arsenopyrite-rich veins on the hill northwest of the Granduc millsite; and several gold-bearing, banded or crustified quartz veins around the margin of the Texas Creek granodiorite on the Alaska Star property (Fig. 118).

Precious metal deposition occurred within the period 190 to 50 Ma, but no evidence exists to allow for a more specific time of mineralization to be determined. The vein deposits clearly postdate map unit 1 and no veins are reported within the epiclastic rocks or carbonaceous siltstones of map units 2 and 4. Most veins predate the emplacement of the major dyke swarms, although the Blueberry vein near the Scottie Gold camp is localized in a shear zone that cuts a hornblende-porphyritic lamprophyre dyke (P. McGuigan, personal communication, 1984).

The author believes that formation of the precious and base metal veins of categories (1) to (4) was related to the period of shallow submarine sulphide deposition which accompanied the waning stages of felsic volcanism and deposition of unit 4a. This event slightly postdates deposition and lithification of the pyritic lapilli tuff and the black tuff (units 3e and 3f). Angular fragments of sulphides and chalcedony in mineralized veins of categories (2) and (3) suggest repeated episodes of vein formation and sulphide deposition.

The veins of categories (5) and (6) apparently accompanied intrusion of the 50 Ma Hyder quartz monzonite.

CONCLUSIONS

A differentiated andesitic to dacitic calc-alkaline volcanic pile with interbedded sedimentary facies hosts precious metal-rich vein deposits of the Salmon River valley. These Upper Triassic to Lower Jurassic subaerial volcanic rocks are overlain by sedimentary rocks of Middle Jurassic age. Facies variations indicate that volcanic vents and paleotopographic highs were centred at Mount Dillworth and at Long Lake; other volcanic centres were likely located nearby.

A coeval, epizonal subsidiary magma chamber underlay the Mesozoic stratovolcano at a depth of about 2 kilometres. From this chamber, late magmatic, bimodal feldspar-porphyritic feeder dykes and volcanic necks were injected which cut the entire andesite sequence and extruded at surface.

The many gold-silver-bearing veins of the belt show regional zoning patterns with respect to sulphide mineral associations, vein textures, and silver:gold ratios. The zoning is spatially related to the coeval Texas Creek pluton and to the stratigraphic position of the veins within the volcanic-sedimentary sequence. The precious metal veins are late to post-intrusive epithermal veins that were emplaced in the andesitic to dacitic host rocks at the close of felsic volcanic activity, about 180 Ma ago.

A later episode of silver-rich galena-sphalerite-freibergite vein formation is related to intrusion of biotite granodiorite stocks of the Coast Plutonic Complex during Eocene time. Tungsten and molybdenum deposits in the area may represent deeper level deposits of this intrusive episode.

ACKNOWLEDGMENTS

It is a pleasure to acknowledge the hospitality and logistical support provided by Scottie Gold Mines Limited, Esso Minerals Canada, Westmin Resources Limited, and Pulsar Energy and Resources Limited. My sincere thanks to Bob Anderson, Derek Brown, Garnet Dawson, Paul McGuigan, Dave Nowak, Norm Tribe, and Paul Wojdak for sharing their knowledge and ideas throughout the summer. Jacques Dupas provided capable and cheerful assistance in the field.

REFERENCES

Alldrick, D. J. (1983): Salmon River Project, Stewart, British Columbia (104B/1), *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1982, Paper 1983-1, pp. 182-195.

.... (1984): Geologic Setting of the Precious Metal Deposits in the Stewart Area (104B/1), *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1983, Paper 1984-1, pp. 149-164.

Alldrick, D. J. and Kenyon, J. M. (1984): The Prosperity/Porter Idaho Silver Deposits (103P/13), *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1983, Paper 1984-1, pp. 165-172.

Branch, C. D. (1976): Development of Porphyry Copper and Stratiform Volcanogenic Orebodies During the Life Cycle of Andesitic Stratavolcanoes, *in* Volcanism in Australasia, R. W. Johnson, editor, *Elsevier*, pp. 337-342.

Brew, D. A. and Morrell, R. P. (1983): Intrusive Rocks and Plutonic Belts of Southeastern Alaska, U.S.A., *in* Circum-Pacific Plutonic Terranes, *Geol. Soc. Am.*, Mem. 159, pp. 171-194.

Buddington, A. F. (1929): Geology of Hyder and Vicinity, Southeastern Alaska, *U.S.G.S.*, Bull. 807, 124 pp.

Church, B. N. (1975): Quantitative Classification and Chemical Comparison of Common Volcanic Rocks, *Geol. Soc. Am.*, Bull., Vol. 86, pp. 257-263.

.... (1978): Shackanite and Related Analcite-bearing Lavas in British Columbia, *Cdn. Jour. Earth Sci.*, Vol. 15, pp. 1669-1672.

Galley, A. (1981): Volcanic Stratigraphy and Gold-silver Occurrences on the Big Missouri Claim Group, Stewart, British Columbia, M.Sc. thesis, *Univ. of Western Ontario,* 181 pp.

Gill, J. B. (1981): Orogenic Andesites and Plate Tectonics, *Springer-Verlag*, 390 pp.

Grove, E. W. (1971): Geology and Mineral Deposits of the Stewart Area, British Columbia, *B.C. Ministry of Energy, Mines & Pet. Res.*, Bull. 58, 219 pp.

.... (1973): Geology and Mineral Deposits of the Stewart Complex, British Columbia, Ph.D. thesis, *McGill Univ.*, 434 pp.

.... (1983): Geology of the Unuk River-Salmon River-Anyox Map-area, *B.C. Ministry of Energy, Mines & Pet. Res.*, Miscellaneous map series (coloured maps to accompany Bull. 63, in preparation).

Hanson, G. (1929): Bear River and Stewart Map-areas, Cassiar District, British Columbia, *Geol. Surv., Canada,* Mem. 159, 84 pp.

.... (1935): Portland Canal Area, British Columbia, *Geol. Surv., Canada*, Mem. 175, 179 pp.

Henley, R. W. and Ellis, A. J. (1983): Geothermal Systems Ancient and Modern: A Geochemical Review, *Earth Sci. Rev.*, Vol. 19, pp. 1-50.

Palmer, A. R. (1983): The Decade of North American Geology 1983 Geologic Time Scale, *Geology*, Vol. 11, pp. 503, 504.

Schofield, S. J. and Hanson, G. (1922): Geology and Ore Deposits of Salmon River District, British Columbia, *Geol. Surv., Canada*, Mem. 132, 81 pp.

Sillitoe, R. H. and Bonham, H. F. Jr. (1984): Volcanic Landforms and Ore Deposits, *Econ. Geol.*, Vol. 79, pp. 1286-1298.

Smith, J. G. (1977): Geology of the Ketchikan D-1 and Bradfield Canal A-1 Quadrangles, Southeastern Alaska, *U.S.G.S.*, Bull. 1425, 49 pp.

Steiger, R. H. and Jager, E. (1977): Submission on Geochronology: Convention on the Use of Decay Constants in Geo- and Cosmochronology, *Earth Planet. Sci. Lett.*, Vol. 36, pp. 359-362.

Tipper, H. W. and Richards, T. A. (1976): Jurassic Stratigraphy and History of North-central British Columbia, *Geol. Surv., Canada*, Bull. 270, 73 pp.

Wares, R. and Gewargis, W. (1982): Scottie Gold Mines Surface Geology Map Series, *B.C. Ministry of Energy, Mines & Pet. Res.*, Assessment Report 10738.

White, W. E. (1946): Big Four Silver Mines Ltd., *Minister of Mines, B.C.*, Ann. Rept., 1946, pp. 74-78.

Williams, H. and McBirney, A. R. (1979): Volcanology, *Freeman, Cooper and Co.*, 397 pp.

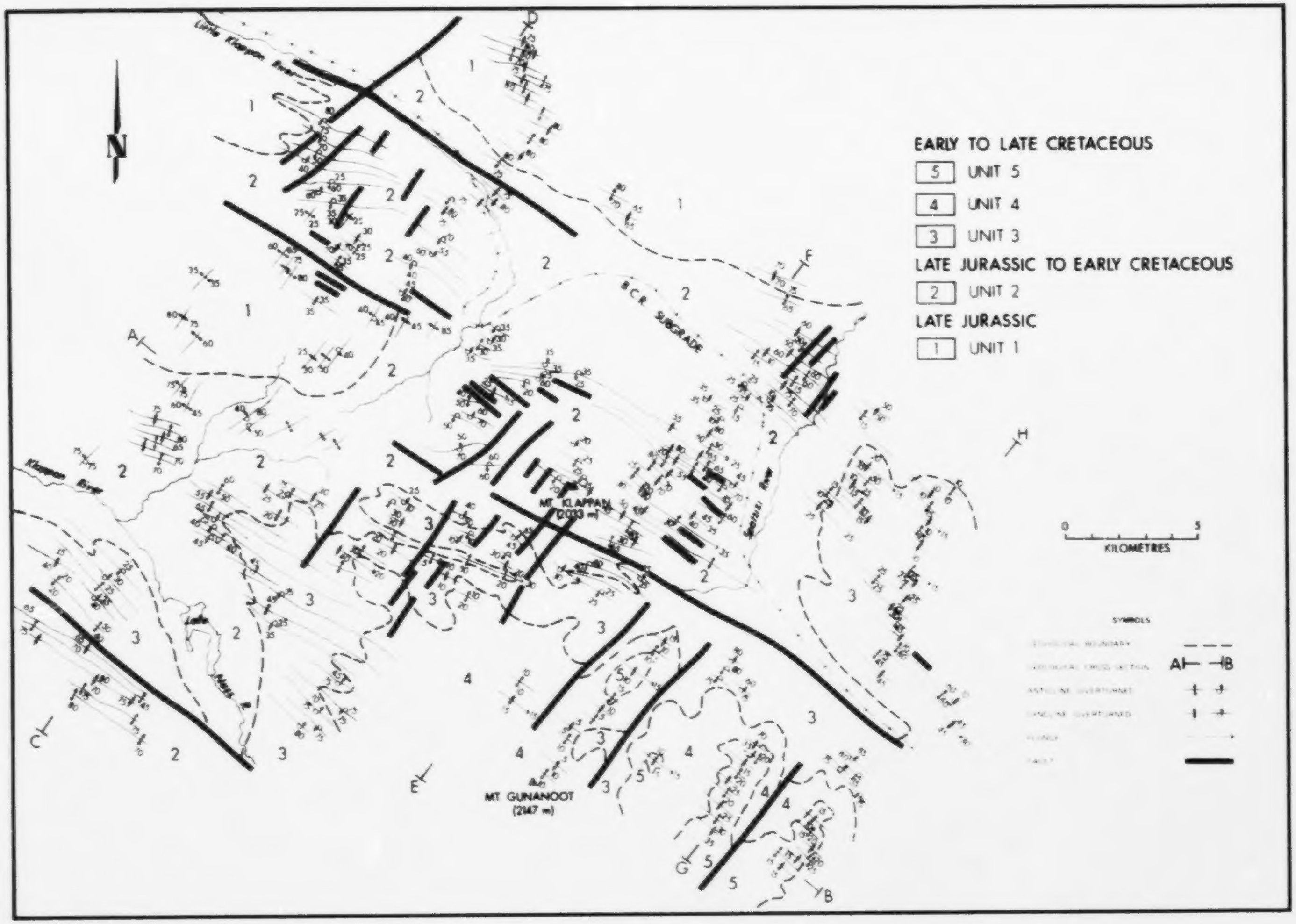

N
Little Klappan River
Klappan River
Nass R.
B C R SUBGRADE
Spatsizi River
MT. KLAPPAN (2033 m)
MT GUNANOOT (2147 m)
A
B
C
D
E
F
G
H
EARLY TO LATE CRETACEOUS
5 UNIT 5
4 UNIT 4
3 UNIT 3
LATE JURASSIC TO EARLY CRETACEOUS
2 UNIT 2
LATE JURASSIC
1 UNIT 1
0
5
KILOMETRES
SYMBOLS
GEOLOGICAL BOUNDARY
GEOLOGICAL CROSS SECTION
ANTICLINE OVERTURNED
SYNCLINE OVERTURNED
FAULT

Figure 119. Geology of the Mount Klappan area.

COAL GEOLOGY OF THE MOUNT KLAPPAN AREA IN NORTHWESTERN BRITISH COLUMBIA

(104H/2, 3, 6, 7)

By J. Koo

INTRODUCTION

The Mount Klappan area is approximately 150 kilometres northeast of Stewart and 500 kilometres northeast of Prince Rupert in northwestern British Columbia. Gulf Canada Resources Inc. has been conducting coal exploration in the Mount Klappan area since 1981.

The present project began with a reconnaissance survey of the Mount Klappan area during the summer of 1983 (Koo, 1984). Fieldwork was continued during the summer of 1984 to investigate the Mount Klappan area in more detail. This report presents preliminary results from work done during the 1984 field season in a 250-square-kilometre area in the Mount Klappan region (Figs. 119 and 120). Objectives of this project are to increase the understanding of the stratigraphy, depositional environment, structural development, and relationships with surrounding rocks of the coal measures in the Mount Klappan area.

REGIONAL GEOLOGICAL FRAMEWORK

The Mount Klappan area is located in the northwestern part of the Groundhog Coalfield within the northeastern portion of the Bowser Basin. Uplift of the Skeena Arch in Middle Jurassic time separated the Early to Middle Jurassic Hazelton eugeosynclinal trough into the Bowser and the Nechako Basins (Tipper and Richards, 1976). The Stikine Terrane, the Atlin Terrane, and the Omineca Crystalline Belt merge in the vicinity of the Bowser Basin. Tectonic interactions of the three crustal blocks controlled sedimentation in the Bowser Basin (Eisbacher, 1981). The Groundhog Coalfield contains about 3 500 metres of Late Jurassic to Cretaceous marine and non-marine strata. Eisbacher (1974b) subdivided the sedimentary strata at the eastern margin of the Bowser Basin into three facies that were referred to as the Duti River-Slamgeesh, Groundhog-Gunanoot, and Jenkins Creek. Richards and Gilchrist (1979) divided the stratigraphic succession in the Groundhog Coalfield into four map units that were referred to as channel, channel-overbank, overbank-channel, and overbank facies. More recently Bustin and Moffat (1983) revised this succession into four stratigraphic units; in ascending order these are the Jackson, the Currier or Prudential, the McEvoy, and the Devil's Claw units. The Groundhog succession unconformably overlies the Triassic to Middle Jurassic Takla-Hazelton assemblage and is unconformably overlain by the Late Cretaceous Tango Creek Formation of the Sustut Group (Eisbacher, 1974a, 1974b).

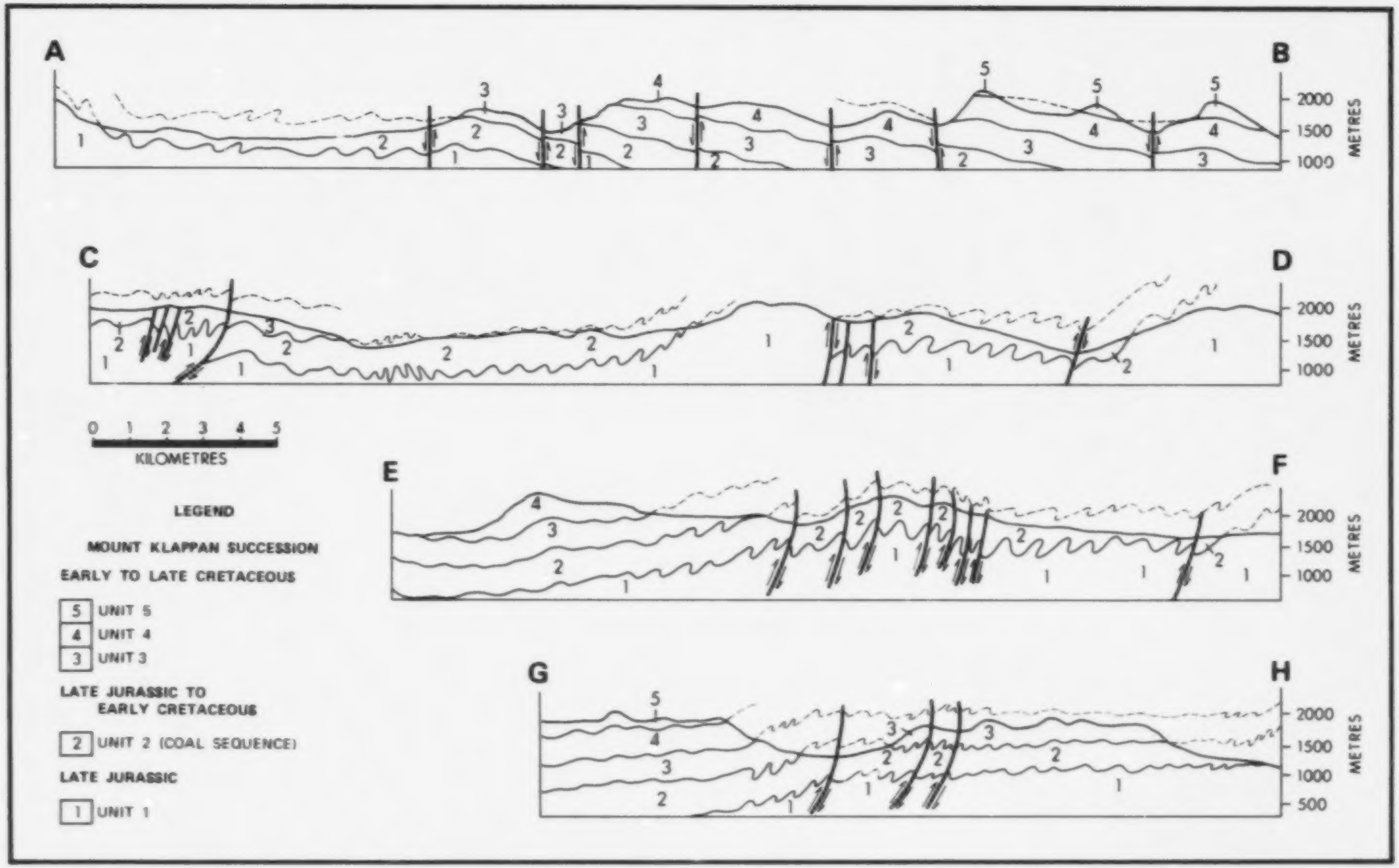

A
B
C
D
E
F
G
H
METRES
2000
1500
1000
500
0 1 2 3 4 5
KILOMETRES
LEGEND
MOUNT KLAPPAN SUCCESSION
EARLY TO LATE CRETACEOUS
5 UNIT 5
4 UNIT 4
3 UNIT 3
LATE JURASSIC TO EARLY CRETACEOUS
2 UNIT 2 (COAL SEQUENCE)
LATE JURASSIC
1 UNIT 1

Figure 120. Geological cross-sections of the Mount Klappan area.

The Mount Klappan area is underlain by a 1 300 to 1 500-metre succession of conformable marine and non-marine strata, referred to here as the Mount Klappan succession. It consists of coal seams, claystones, siltstones, sandstones, and conglomerates. Johnson and Pituley (1984) divided the succession into the lowest marine, Klappan, Malloch, and Rhonda sequence in ascending order. The present study divided the Mount Klappan succession into five mappable stratigraphic units that are numbered 1 to 5 in ascending order (Figs. 119 and 120). These units correlate closely with those of Bustin and Moffat (1983) and Johnson and Pituley (1984), except the McEvoy unit or the Malloch sequence which the present study subdivided into units 3 and 4.

STRATIGRAPHY

UNIT 1

Unit 1 is the lowest 200-metre stratigraphic interval of the Mount Klappan succession. It is exposed widely in the northwestern part of the Mount Klappan area (Fig. 119). Gabrielse and Tipper (1984) mapped the Middle to Late Jurassic Bowser Lake Group in the Spatsizi area immediately to the north. Unit 1 correlates with part of the upper sequence of the Bowser Lake Group. Up to 11 coarsening upward cycles are included in this unit; individual cycle thicknesses vary from 2 to 50 metres. The cycles consist mainly of interbeds of grey to black claystones and siltstones, and grey to brown fine to medium-grained sandstones; claystones and siltstones are three to five times as abundant as sandstones. Claystone and siltstone layers are up to 40 metres thick; beds within them are 1 to 5 centimetres thick. About 10 per cent of the layers are impure carbonate interlayers that range in thickness from 0.5 to 2 metres. The sandstones range in thickness from 1 to 5 metres and are planar-bedded. Marine bivalves and intense bioturbation are common in the layers of intercalated siltstones and sandstones. Conglomerate occurs in a few lenticular layers up to 5 metres thick near the top of this unit; clasts in the conglomerate consist of subrounded chert and volcanic pebbles up to 3 centimetres in diameter. In places, it grades into thin discontinuous coarse-grained sandstone lenses. Unit 1 typifies a marine deltaic sequence. The coarsening upward cycles result from successive progradation of delta channels over fine-grained prodelta sediments.

UNIT 2

Unit 2 is the principal coal-bearing sequence of the Mount Klappan area. Its thickness ranges from 350 to 420 metres and it occurs mainly at lower elevations in the central part of the area (Figs. 119 and 120). This unit can be subdivided into lower, middle, and upper members. The lower member, which ranges in thickness from 150 to 200 metres, contains seven to eleven coarsening upward cycles, each between 6 and 30 metres in thickness. The cycles begin with grey to black interbedded claystones and siltstones and grade upward to grey to brown fine to coarse-grained sandstones. In the lower member, the total amount of claystone and siltstone is about twice as much as that of sandstone. Claystone and siltstone layers are as thick as 20 metres; commonly they are associated with coal seams. The sandstone layers, which are up to 10 metres thick, have widespread ripple crossbedding. Grains in the sandstones consist mainly of chert, feldspar, and volcanic rocks. A few lenticular layers of conglomerate occur in the upper zone of the lower member; they are up to 5 metres thick and 200 metres in lateral extent. Bivalves and bioturbation occur in some siltstone layers that appear to be of marine origin. The lower member is the type of sequence found in a constructive deltaic system with wide, subaerial delta plains and intermittent coal swamps.

The middle member of unit 2 consists mainly of dark grey to brown claystones, siltstones, and fine to medium-grained sandstones; it ranges in thickness from 100 to 150 metres. Only a minor amount of coarse-grained sandstone occurs as thin lenses at the base of this member. The total amount of claystone and siltstone is almost equal to that of sandstones in the member; all three are closely intercalated. Individual beds vary from a few centimetres to 3 metres in thickness; scours, mud cracks, and rip-ups are widespread. Despite the intercalations, six to ten fining upward and two coarsening upward cycles with individual thickness from 10 to 30 metres can be recognized. Dwarfed, brackish water bivalves and bioturbation occur in a few black mudstone zones within the coarsening upward cycles. This member comprises mainly fluvial cycles that are intertongued by several marine cycles. The environment of deposition varied between marine deltaic and non-marine fluvial conditions.

The upper member of unit 2 consists of 100 meters of claystones, siltstones, sandstones, and conglomerates. Up to 12 fining upward cycles occur; they range from 6 to 35 metres in thickness. The claystones and siltstones, which are approximately twice as abundant as the sandstones, are black to grey, show widespread mud cracks and rip-up clasts, and form layers that range in thickness from 2 to 15 metres. They are closely associated with the potentially economic coal seams. The sandstones are fine to coarse grained, dark grey to brown, and form lenticular layers up to 10 metres thick. They are composed of chert, feldspar, and volcanic rock grains. The conglomerates comprise lenticular layers with erosional bases that represent channel-fill deposits. These layers are as thick as 6 metres and gradually wedge out laterally over distances of about 100 metres. The lowest conglomerate layer, which marks the base of the member, consists mainly of chert and volcanic pebbles that are up to 6 centimetres across. The upper member of unit 2 was deposited in a fluvial channel and backswamp environment.

UNIT 3

Unit 3 is comprised of 220 metres of mudstones, sandstones, and conglomerates in up to 20 fining upward cycles. It is exposed mainly at intermediate elevations in the central part of the Mount Klappan area (Figs. 119 and 120). Cycles vary in individual thickness from 5 to 30 metres. The mudstone layers are dark grey to brown, 30 centimetres to 8 metres in thickness, and locally calcareous or carbonaceous; they are associated with coal seams up to 30 centimetres thick. Petrified tree trunks are widespread in unit 3. The sandstones consist mainly of chert and volcanic rock grains with a minor amount of feldspar. They are fine to coarse grained and dark grey to brown. The sandstone layers range from 30 centimetres to 8 metres in thickness and from 10 to 300 metres in lateral extent. The conglomerate consists mainly of subrounded chert and volcanic pebbles 1 to 6 centimetres across. It forms lenticular layers that have erosional bases, are 2 to 7 metres thick, and extend laterally for about 200 metres. The lowest conglomerate layer forms the base of unit 3. The sequence of rocks in unit 3 were deposited in an environment which was changing from fluvial plains to distal alluvial fans.

UNIT 4

Unit 4 consists mainly of coarse to medium-grained sandstones and conglomerate with minor amounts of fine-grained sandstone and mudstone. It contains as many as eight fining upward cycles and ranges in thickness from 280 to 300 metres. Unit 4 rocks are exposed widely at higher elevations in the southern part of the Mount Klappan area (Figs. 119 and 120). The coarse to medium-grained sandstones consist largely of grey chert and volcanic rock grains; volumetrically these sandstones are almost three times as abundant as the other components - conglomerate, fine-grained sandstone, and mudstone. Layers in the coarse to medium-grained sandstone are 2 to 30 metres thick and have widespread crossbedding. Conglomerates consist of subrounded chert and volcanic pebbles in a matrix of coarse-grained sandstone. They occur in about 10 layers that vary from 30 centimetres to 5 metres in thickness. Layers of conglomerate and coarse to medium-grained sandstone have a lateral extent of up to 300 metres; conglomerate commonly grades laterally into coarse to medium-grained sandstone. The lowest conglomerate or sandstone layer marks the base of unit 4. The fine-grained sandstones and mudstones commonly are carbonaceous and 2 to 4 metres thick. Unit 4 rocks represent an environment in which a series of distal alluvial fans were crossed by a system of braided streams.

UNIT 5

Unit 5 is up to 170 metres in thickness and consists mainly of conglomerate and coarse to medium-grained sandstone; fine-grained sandstone and mudstone comprise only 10 per cent of the total sequence. A maximum of eight fining upward cycles constitute the unit. This unit is exposed at higher elevations in the southeastern part of the Mount Klappan area. The conglomerate consists of moderately sorted, subrounded chert and volcanic pebbles up to 5 centimetres in diameter; it occurs in five to eight layers with thicknesses from 2 to 30 metres. The coarse to medium-grained sandstone layers are 3 to 30 metres thick, grey to brown, and commonly crossbedded. Conglomerate and sandstone layers have a lateral extent of about 500 metres. The fine-grained sandstones and mudstones commonly are carbonaceous; layers are 2 to 4 metres thick. The sequence of rocks in unit 5 represent an environment in which proximal to intermediate alluvial fans were dissected by streams with braided channels.

COAL DEPOSITION

POTENTIALLY ECONOMIC COAL SEAMS

Potentially economic coal seams occur in the lower, middle, and upper members of unit 2 in the Mount Klappan area. As many as six coal seams occur that are 17 to 50 metres apart in the lower member; individual seams can be 5 metres thick. The coal seams are associated closely with marine mudstones that commonly contain significant amounts of iron sulphide. Up to six coal seams that are 5 to 35 metres apart occur in the middle member; their individual thicknesses can be 5 metres thick. Four more coal seams occur in the upper member; they are 6 to 35 metres apart and their individual thicknesses range up to 8 metres.

Coal seams in unit 2 consist of semi-anthracite, anthracite, and meta-anthracite. Their mean maximum reflectance values of vitrinite in oil range from 2.5 to 5.0 per cent.

DEPOSITIONAL ENVIRONMENTS

The Mount Klappan succession is an accretional megacycle that resulted from a major marine regression in the Mount Klappan basin. The rocks in the succession reflect a gradual transition from marine deltaic through fluvial to alluvial environments. The Mount Klappan succession is an overall coarsening upward megacycle; chert fragments are significant components. The provenance of the succession could be from the north where the chert-bearing Cache Creek Group crops out in the Atlin Terrane (Eisbacher, 1981). The channel loads of streams entering the Mount Klappan basin steadily increased in volume and coarseness, and regression continued. This sediment load, which is marked by sands and gravels in units 1 and 2, built paleodeltas seaward and extended the subaerial part of the deltaic system until the whole Mount Klappan basin was gradually infilled; this time is represented by fluvial sedimentary rocks of units 2 and 3. Peat swamps flourished on the subaerial delta and fluvial plains during deposition of unit 2. Overbank deposits inundated some swamps, and others disappeared due to shifts in drainage patterns; consequently, several coal seams occur in the unit 2 sequence. Conditions gradually changed and the peat swamps slowly disappeared as they were overridden by progressively coarsening fluvial and alluvial sediments transported into the basin by streams flowing in from the north.

Potentially economic coal seams, which occur in unit 2, formed during the transitional period between the deposition of marine-dominated and non-marine-dominated sequences of the Mount Klappan succession. Marine conditions ended during deposition of the middle member of unit 2, at the top of the Bowser Lake Group. This boundary also appears to separate Jurassic and Cretaceous sequences; therefore, the economic coal seams may range in age from Late Jurassic to Early Cretaceous. Seams in the unit 2 lower member can be correlated with the upper part of the Middle to Late Jurassic Bowser Lake Group, and seams of the unit 2 upper member can be correlated with the lower part of the Early to Late Cretaceous Skeena Group (Koo, 1984).

DEFORMATION

Two phases of post-sedimentary deformation affected the Mount Klappan succession. Folds trend northwesterly and northeasterly, respectively. The northwesterly trending deformation occurred first; it created a major synclinorium with associated minor folds and faults. The synclinorium comprises the northwestern part of the Beirnes syncline of the Groundhog Coalfield (Richards and Gilchrist, 1979); the Mount Klappan area lies within the synclinorium, which embraces the whole Mount Klappan succession. Its core zone is best outlined by exposures of units 4 and 5 in the southern part of the Mount Klappan area. The synclinorium is apparently asymmetrical with gently folded limbs and a vertical axial plane. Its axial surface strikes north 35 to 45 degrees west and its axis plunges 10 to 35 degrees to the southeast. The east and west limbs of the synclinorium dip approximately 35 degrees to the southwest and to the northeast, respectively.

The minor folds of the synclinorium vary in style depending on the lithology. Minor fold amplitudes range from 200 to 400 metres, and wavelengths from 100 to 400 metres. Their hinges plunge 10 to 35 degrees to the southeast parallel to the axis of the synclinorium. Minor folds in the competent rocks of units 4 and 5 are mainly open symmetrical in style; less commonly, box folds occur in relatively thick zones of fine to medium-grained sandstones and mudstones.

Phase 1 deformation is more intense in the less competent units -- 1, 2, and 3. The minor folds in these units are mainly asymmetric chevrons or nearly isoclinal in style. Their limbs and axial traces are commonly inclined to the southwest on the northeast limb of the synclinorium, and to the northeast on the southwest limb. The dips of the limbs range from 25 to 85 degrees. The steeply dipping limbs of the asymmetric chevron folds are associated closely with thick layers of incompetent claystone, siltstone, and fine-grained sandstone, and are commonly overturned. The gently dipping limbs of these folds occur in the competent stratigraphic intervals that are dominated by conglomerate and coarse to medium-grained sandstone. Box-shaped or open symmetric folds commonly are associated with the competent stratigraphic intervals. Disharmonic folds occur locally in adjacent layers of sandstones and mudstones. The potentially mineable coal seams are generally in the gently dipping limbs where they are amenable to extraction by surface mining methods.

Phase 1 faults and shear zones strike 25 degrees north to 50 degrees west and dip 40 to 80 degrees to the southwest. Nearly isoclinal, overturned folds commonly occur within competent stratigraphic intervals in proximity to major phase 1 faults. Movements on the faults are generally reverse and range from a few metres to 300 metres. The phase 1 faults and shear zones frequently disrupt the steeply dipping axial planes and limbs of the chevron or isoclinal folds. The shear zones range up to 300 metres in width, and commonly grade into sets of faults. The faults and shear zones represent loci of intense deformation that was initiated during phase 1 deformation but continued beyond the period of folding. Coal seams in these structures are stretched or dismembered into lenticular bodies.

Phase 1 structures are deformed and cut by northeasterly trending folds and faults. Phase 2 faults strike north 30 to 60 degrees east and dip almost vertically; displacements on them are mainly vertical and range up to 500 metres. Most of the faults are associated with a series of southeasterly dipping monoclines in units 4 and 5.

Phase 2 folds are mainly open symmetric or tightly angular chevron folds that are overturned in places. Fold axial planes strike north 30 to 60 degrees east with dips from vertical to 40 degrees to the northwest. Amplitudes range from 50 to 400 metres, and wavelengths from 300 to 2 000 metres; amplitudes are larger and wavelengths smaller in the northwest part of the Mount Klappan area than in the southeast. Phase 2 folds refold phase 1 folds; consequently, phase 1 axial traces became curved, and axes become doubly plunging; phase 1 axes now plunge 10 to 35 degrees either southeast or northwest.

CONCLUSIONS

The Mount Klappan succession is an accretional megacycle deposited during a time of marine regression. The potentially economic coal seams occur in a transitional unit between the marine and non-marine sequences. The coal seams are of marine deltaic and non-marine fluvial origin. Two phases of post-sedimentary deformation resulted in folding, cross-folding, and faulting of the Mount Klappan succession. Deformation was most intense in the less competent, coal-bearing sequence than in other sequences; nevertheless, low angle, near-surface fold limbs provide favourable structural sites for potential future surface mining of the coal seams in the sequence of unit 2.

ACKNOWLEDGMENTS

The author extends sincere thanks to: B. P. Flynn, V. Duford, G. Seve, E. Swanbergson, S. McKenzie, and K. Jenner of Gulf Canada Resources Inc.

for their generous cooperation; K. Foellmer for his capable field assistance; and W. J. McMillan and W. Kilby for constructive criticism of an early version of this paper.

REFERENCES

Bustin, R. M. and Moffat, I. (1983): Groundhog Coalfield, Central British Columbia: Reconnaissance Stratigraphy and Structure, *Cdn. Pet. Geol.*, Bull., Vol. 31, No. 4, pp. 231-245.

Eisbacher, G. H. (1974a): Sedimentary and Tectonic Evolution of the Sustut and Sifton Basins, North-central British Columbia, *Geol. Surv., Canada*, Paper 73-31, 57 pp.

.... (1974b): Deltaic Sedimentation in the Northeastern Bowser Basin, British Columbia, *Geol. Surv., Canada*, Paper 73-33, 13 pp.

.... (1981): Late Mesozoic-Paleogene Bowser Basin Molasse and Cordilleran Tectonics, Western Canada, *Geol. Assoc. Can.*, Special Paper 23, pp. 125-151.

Gabrielse, H. and Tipper, H. W. (1984): Bedrock Geology of Spatsizi Map-area (104H), *Geol. Surv., Canada*, Open File 1005.

Johnson, A. A. and Pituley, L. J. (1984): Mount Klappan Anthracite: The Other Coal, *C.I.M.*, Bull., Vol. 77, No. 863, p. 90.

Koo, J. (1984): The Telkwa, Red Rose, and Klappan Coal Measures in Northwestern British Columbia, *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1983, Paper 1984-1, pp. 81-90.

Richards, T. A. and Gilchrist, R. D. (1979): Groundhog Coal Area, British Columbia, *Geol. Surv., Canada*, Paper 79-1B, pp. 411-414.

Tipper, H. W. and Richards, T. A. (1976): Jurassic Stratigraphy and History of North-central British Columbia, *Geol. Surv., Canada*, Bull. 270, 73 pp.

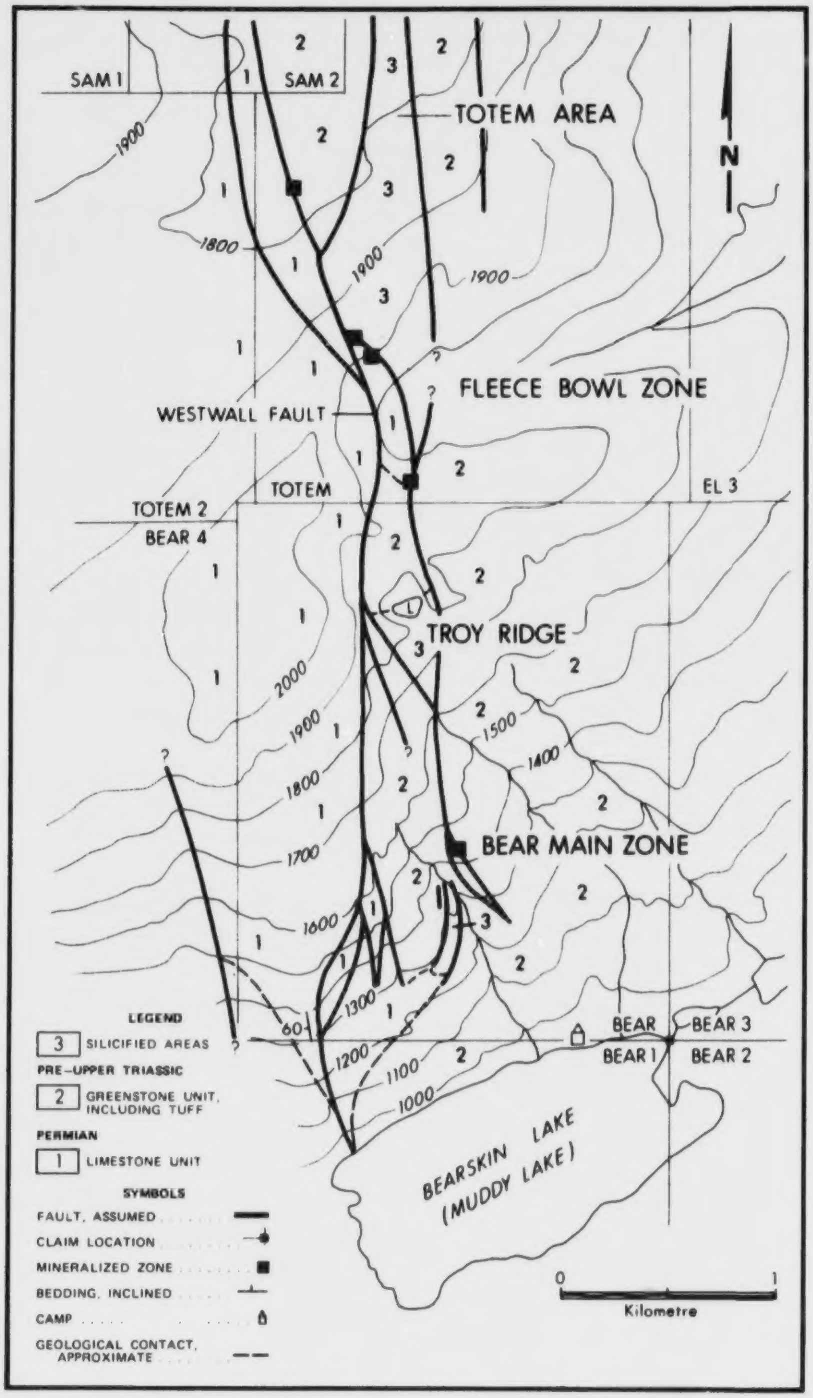

SAM 1
SAM 2
TOTEM AREA
N
FLEECE BOWL ZONE
WESTWALL FAULT
TOTEM
TOTEM 2
BEAR 4
EL 3
TROY RIDGE
BEAR MAIN ZONE
BEAR
BEAR 1
BEAR 2
BEAR 3
BEARSKIN LAKE (MUDDY LAKE)
1900
1800
2000
1700
1600
1500
1400
1300
1200
1100
1000
60
0
1
Kilometre
LEGEND
3 SILICIFIED AREAS
PRE-UPPER TRIASSIC
2 GREENSTONE UNIT, INCLUDING TUFF
PERMIAN
1 LIMESTONE UNIT
SYMBOLS
FAULT, ASSUMED
CLAIM LOCATION
MINERALIZED ZONE
BEDDING, INCLINED
CAMP
GEOLOGICAL CONTACT, APPROXIMATE

Figure 121. Geological plan of the Muddy Lake prospect (after company plans).

MUDDY LAKE PROSPECT

(104K/1W)

By T. G. Schroeter

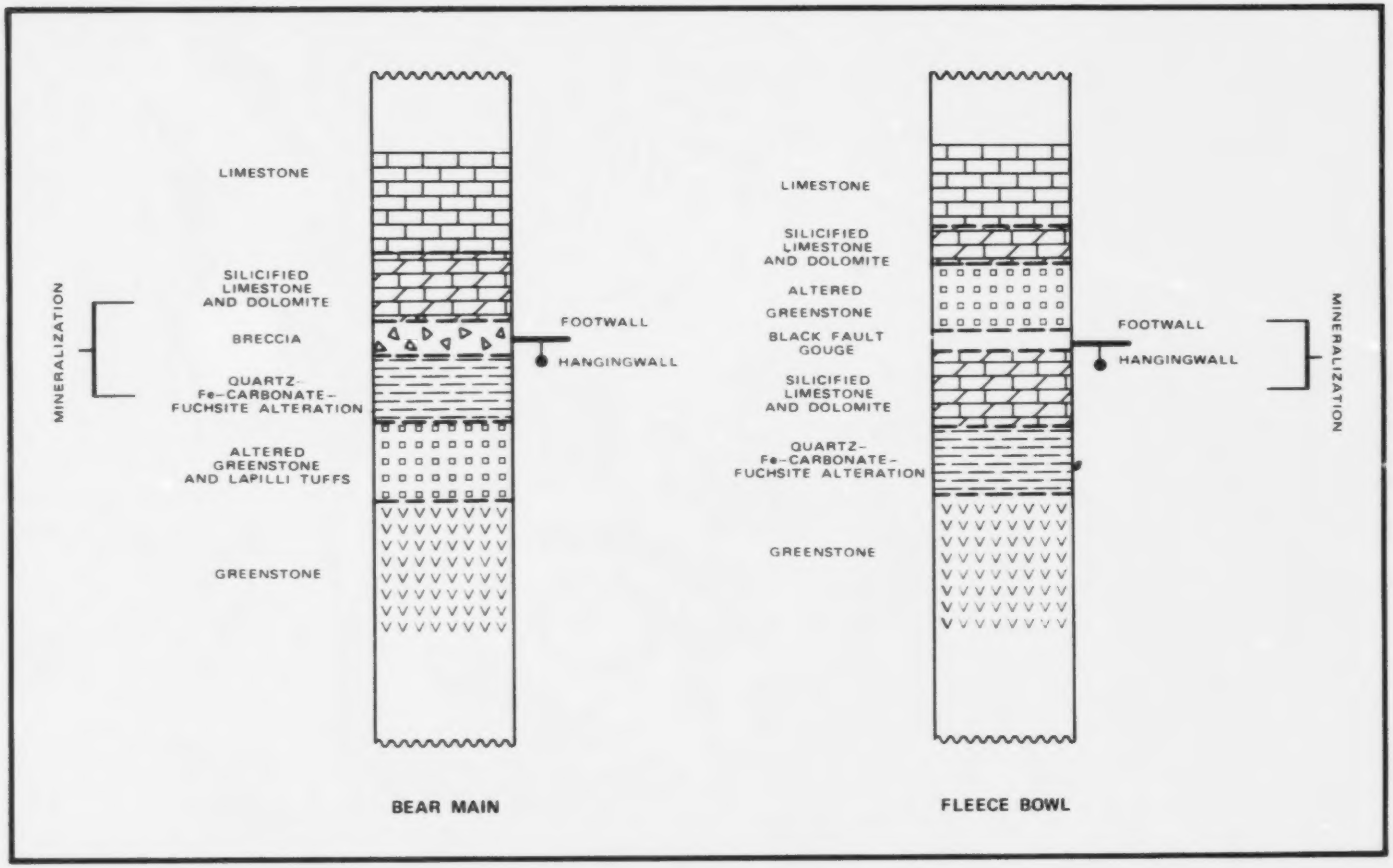
INTRODUCTION

The Muddy Lake gold property consists primarily of the Bear and Totem group of claims and is located 137 kilometres west of Dease Lake at latitude 58 degrees 13 minutes north and longitude 132 degrees 17 minutes west. The claims lie immediately north of Bearskin Lake (locally called Muddy Lake), approximately 10 kilometres due south of Tatsamenie Lake (Fig. 121). Access is by float plane to Muddy Lake, or by helicopter from either Dease Lake or Atlin. A winter tote route connects the property with Telegraph Creek, approximately 75 kilometres to the southeast. The claims are owned by Chevron Canada Limited who have been actively involved in the region since 1980. They own several other claim groups in the vicinity of Tatsamenie Lake, including Misty, Nie, Iver, Highliner, Grand, Slam, Pole, and others. During 1983, 30 diamond-drill holes were completed, mainly on the Bear Main Zone (Bear claim), utilizing one to three drills. During 1984, a further 56 holes totalling approximately 10 000 metres were completed on two zones of interest using three to four drills. The base camp housed approximately 35 people and included an assay lab. The writer spent one and one half days on the property in late August 1984.

PROPERTY GEOLOGY

The zones of interest are within an assemblage of pre-Upper Triassic oceanic sedimentary and volcanic rocks and Triassic dioritic rocks (Souther, 1971). The pre-Upper Triassic rocks are comprised of pelagic sediments (mainly argillites and shales), carbonate bank limestone (mainly crinoid debris) and mafic volcanic and volcaniclastic rocks. The limestones have yielded Permian age dates from fusulinids (Geological Survey of Canada identification; H. Wober, personal communication) and are considered to be part of the Stikine Terrane assemblage rather than Cache Creek Group.

The western third of the property is predominantly limestone while the eastern two-thirds is predominantly greenstone and chloritic phyllite. The limestone unit is relatively pure and massive (compare, Carlin, Nevada) and thus may have been a very difficult rock unit for mineralizing solutions to penetrate. It occurs in varying shades of grey to white to black to pink - probably reflecting various concentrations of organic material and/or hematite. Limestone outcrops exhibit a homogeneous, sugary texture, almost unfractured but with a distinct layering which is best observed at a distance. Fossils are not abundant. Primary breccias occur as conformable layers within the limestone section and



MINERALIZATION
LIMESTONE
SILICIFIED LIMESTONE AND DOLOMITE
BRECCIA
QUARTZ-Fe-CARBONATE-FUCHSITE ALTERATION
ALTERED GREENSTONE AND LAPILLI TUFFS
GREENSTONE
FOOTWALL
HANGINGWALL
BEAR MAIN
LIMESTONE
SILICIFIED LIMESTONE AND DOLOMITE
ALTERED GREENSTONE
BLACK FAULT GOUGE
SILICIFIED LIMESTONE AND DOLOMITE
QUARTZ-Fe-CARBONATE-FUCHSITE ALTERATION
GREENSTONE
FOOTWALL
HANGINGWALL
MINERALIZATION
FLEECE BOWL

Figure 122. Schematic sections showing relationships of alteration and mineralization, Muddy Lake prospect.

consist of angular to subangular clasts of limestone in a fine-grained carbonate mixture.

The greenstone unit is overprinted with greenschist facies metamorphism; it includes greenstone (overprinting of greenschist facies regional metamorphism), chloritic phyllite, gabbro (dykes and/or sills), augite porphyry, lapilli tuff, and aphanitic tuff. Fractures within the greenstone unit are commonly coated with chlorite, epidote and hematite.

STRUCTURE

A prominent and significant northerly to north-northwesterly trending fault zone (locally referred to as the Ophir Break Zone) extends through the property. It is defined by areas of intense fracturing, abundant slickensiding, and linear alteration zones consisting of Fe-carbonate, quartz±fuchsite and quartz-dolomite. The Ophir Break Zone may be as wide as 1 kilometre and several minor fault structures occur within it (personal communication, H. Wober). The faults appear to control development of the alteration zones; rocks between faults are relatively unaltered. Folding, especially in the limestone unit, has been observed by Chevron personnel.

ALTERATION

Two major alteration types exist:

(1) A quartz-dolomite assemblage which occurs primarily in the limestone unit;

(2) A quartz-Fe-carbonate-pyrite±fuchsite assemblage.

Both types are most intensely developed along fault zones.

The quartz-dolomite alteration consists of massive, fine-grained quartz, quartz breccia, and lesser dolomite. Outward from a zone of intense silicification, with or without brecciation, silica decreases and progresses from massive quartz to vein quartz to stringer quartz in a dolomite matrix. Further out, alteration grades into dolomite-limestone and finally to unaltered limestone. The dolomitic alteration may be due to release of magnesium from the adjacent greenstone unit. Brecciation is locally well developed in the quartz-dolomite alteration zone and consists of angular clasts in a fine-grained vuggy quartz matrix.

The quartz-Fe-carbonate-pyrite±fuchsite alteration assemblage is restricted mainly to rocks of the greenstone unit. The width or extent of altered zones depends upon the permeability of the host rocks but can be as much as 20 metres. Rare sericite has been observed.

MINERALIZATION

Mineralization is literally 'no-seeum' gold with minor silver values. The main sulphide noted is pyrite, which ranges from 0.1 to 5 per cent in the

TABLE 1
GRAB SAMPLES OF ALTERED ROCKS FROM THE MUDDY LAKE PROSPECT

	Sample Number	Description	Zone	Au ppm	Ag ppm	Hg ppb	As ppm	Sb ppm
1.	Bear-84-1	Silicified limestone	Fleece Bowl	2.7	<10	-	30	<2
2.	Bear-84-5	Silicified limestone breccia	Fleece Bowl	<0.3	<10	-	26	<2
3.	Bear-84-7	Silicified tuff limestone	Fleece Bowl	<0.3	<10	125	<5	3
4.	Bear-84-7a	Silicified tuff limestone	Fleece Bowl	<0.3	<10	23	56	9
5.	Bear-84-8	Silicified and pyritized greenstone	Fleece Bowl	<0.3	<10	725	0.31%	15
6.	Bear-84-9	Silicified limestone breccia	Fleece Bowl	<0.3	<10	96	48	9
7.	Bear-84-11	Silicified limestone	Bear (Main) (Tr. 1)	15.6	<10	-	114	2
8.	Bear-84-12	Silicified limestone	Bear (Main) (Tr. 1)	27.8	<10	-	95	8
9.	Bear-84-13	Silicified limestone	Bear (Main)	7.9	<10	-	30	<2
10.	Bear-84-14	Silicified limestone breccia	Bear (Main) (Tr. 4)	5.5	19	-	44	<2
11.	Bear-84-15	Silicified limestone breccia	Bear (Main) (Tr. 4)	9.3	26	-	44	5
12.	Bear-84-16	Silicified limestone breccia	Bear (Main) (Tr. 5)	9.3	11	-	167	8
13.	Bear-84-17	Silicified limestone breccia	Bear (Main) (Tr. 5)	26.0	67	-	875	12
14.	Bear-84-19	Black fault gouge breccia between silicified limestone and greenstone	Fleece Bowl	2.4	<10	224	96	12
15.	Bear-84-20	Silicified pinkish limestone breccia	Fleece Bowl	<0.3	<10	25	20	8
16.	Bear-84-22	Quartz-Fe-carbonate-fuchsite alteration with minor arsenopyrite	Fleece Bowl	<0.3	<10	78	96	7
17.	Bear-84-23	Quartz-Fe-carbonate-fuchsite alteration with pyrite	Fleece Bowl	<0.3	<10	224	56	28
18.	Bear-84-24	Quartz-Fe-carbonate-fuchsite alteration with arsenopyrite	Fleece Bowl	1	<10	4000	7.92%	29
19.	Bear-84-25	Quartz-Fe-carbonate-fuchsite alteration with arsenopyrite	Fleece Bowl	Lost in furnace		1800	4.08%	17
20.	Bear-84-26	Silicified limestone with pyrite	Troy Ridge	<0.3	<10	115	168	<3
21.	Bear-84-27	Quartz-Fe-carbonate-fuchsite alteration	Troy Ridge	<0.3	<10	66	88	<3
22.	Bear-84-28	Limestone breccia	Troy Ridge	<0.3	<10	42	<8	2
23.	Bear-84-29	Foliated hornblende-rich gabbroic rock	Troy Ridge	<0.3	<10	13	<8	<3

Bear Main Zone to trace in some Fleece Bowl mineralization. Trace amounts of arsenopyrite were also observed in some drill holes. Chalcopyrite occurs as amygdules in lapilli tuffs in the Bear Main Zone. Mineralization is of the high-level epithermal type with such characteristics as vuggy quartz, high Au to Ag ratios, and direct geochemical correlation between gold, silver, arsenic, antimony, and mercury.

Two main 'zones' were being tested: Bear Main and Fleece Bowl (Fig. 121). Much of the drilling has been done on the Bear Main Zone; it has indicated a pod of mineralization with a strike length of approximately 110 metres, and an average width of 10 metres. There are two host rocks in the Bear Main Zone; one is silicified limestone-dolomite breccia with a matrix of sugary to fine-grained silica; the second is carbonatized greenstone breccia with a matrix of pyrite and fine-grained rock fragments.

Drilling continued during 1984 on the Troy Ridge area and Fleece Bowl Zone where the host rocks are silicified limestone and dolomite in contact with greenstones; there are associated quartz-Fe-carbonate-pyrite-fuchsite alteration zones. Minor arsenopyrite has also been noted.

The Totem Silica area is a large area of pervasive silicification, similar to what one might expect to see near the top of an epithermal system. Assays of grab samples taken by the writer on the Bear Main Zone, Troy Ridge area, and Fleece Bowl Zone are shown in Table 1.

WORK DONE

During 1984, Chevron diamond drilled approximately 10 000 metres in 56 holes utilizing three to four drills. Detailed geological mapping, geophysical and geochemical surveys were also carried out. Road access was prepared from the base camp to the various mineralized zones.

ACKNOWLEDGMENTS

The writer would like to thank Chevron Canada Resources Limited (especially Helmut Wober and Ken Shannon) for providing access to the property and for their kind hospitality and openess while on the property.

REFERENCES

B.C. Ministry of Energy, Mines & Pet. Res.: Assessment Report 10754.

Souther, J. G. (1971): Geology and Mineral Deposits of Tulsequah Map-Area, British Columbia, *Geol. Surv., Canada*, Mem. 362.

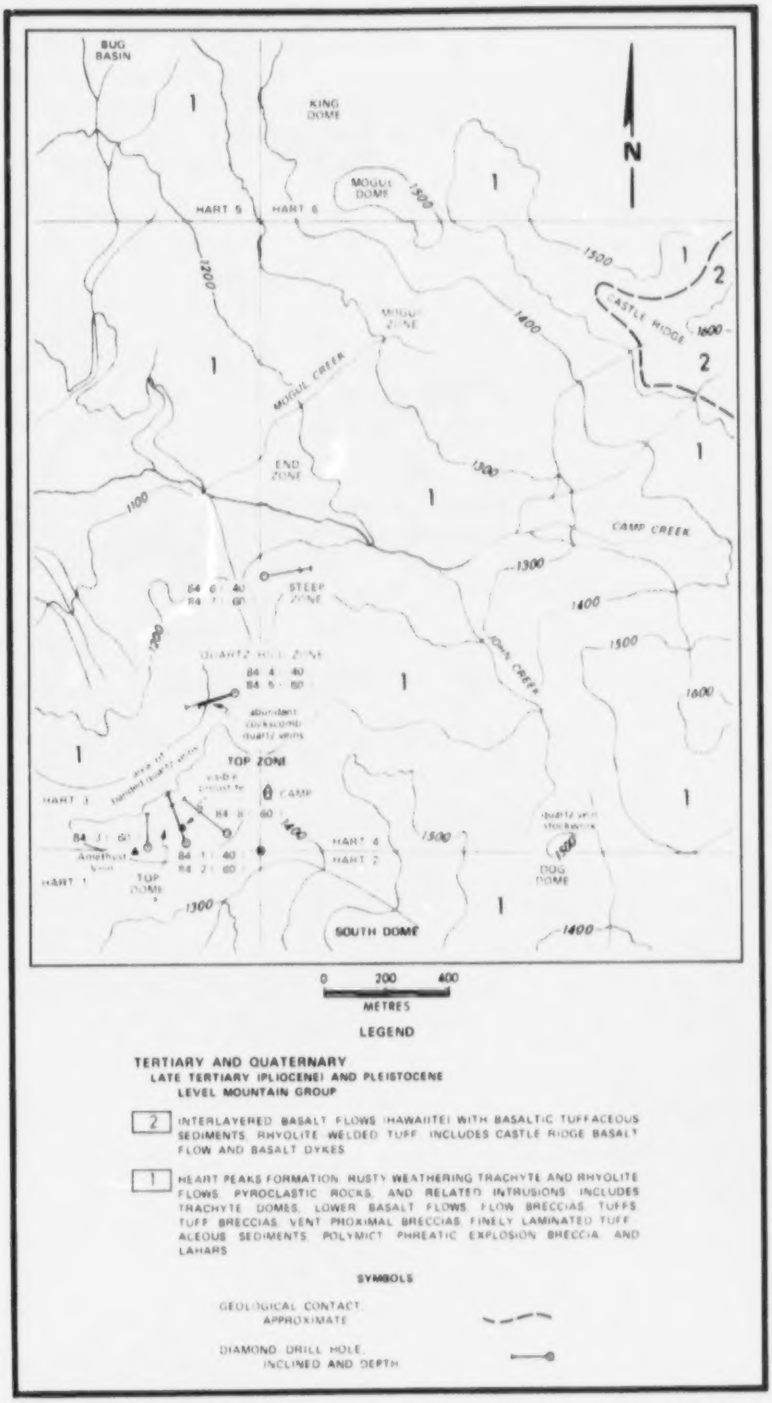

BUG BASIN
KING DOME
N
MOGUL DOME
1500
HART 5
HART 6
1200
1500
CASTLE RIDGE
1600
MOGUL ZONE
1400
MOGUL CREEK
END ZONE
1300
1100
CAMP CREEK
1300
84-6 40
84-7 60
STEEP ZONE
1400
1500
JOHNS CREEK
1200
QUARTZ HILL ZONE
84-4 40
84-5 60
1600
abundant cockscomb quartz veins
area of banded quartz veins
TOP ZONE
CAMP
HART 3
84-8 60
1400
1500
quartz vein stockwork
84-3 60
Amethyst Vein
84-1 40
84-2 60
HART 4
HART 2
1500
HART 1
TOP DOME
DOG DOME
1300
SOUTH DOME
1400
1
2
0
200
400
METRES
LEGEND
TERTIARY AND QUATERNARY
LATE TERTIARY (PLIOCENE) AND PLEISTOCENE
LEVEL MOUNTAIN GROUP
2 INTERLAYERED BASALT FLOWS (HAWAIITE) WITH BASALTIC TUFFACEOUS SEDIMENTS, RHYOLITE WELDED TUFF; INCLUDES CASTLE RIDGE BASALT FLOW AND BASALT DYKES
1 HEART PEAKS FORMATION: RUSTY WEATHERING TRACHYTE AND RHYOLITE FLOWS, PYROCLASTIC ROCKS, AND RELATED INTRUSIONS; INCLUDES TRACHYTE DOMES, LOWER BASALT FLOWS, FLOW BRECCIAS, TUFFS, TUFF BRECCIAS, VENT PROXIMAL BRECCIAS, FINELY LAMINATED TUFFACEOUS SEDIMENTS, POLYMICT PHREATIC EXPLOSION BRECCIA, AND LAHARS
SYMBOLS
GEOLOGICAL CONTACT, APPROXIMATE
DIAMOND DRILL HOLE, INCLINED AND DEPTH

Figure 123. Geological plan of the Heart Peaks prospect (after company plans).

HEART PEAKS PROSPECT
(104K/9E)

By T. G. Schroeter

INTRODUCTION

The Heart Peaks precious metals prospect, consisting of 120 units (Hart 1-6, is located approximately 117 kilometres west of Dease Lake at latitude 58 degrees 36 minutes north and longitude 132 degrees 3 minutes west. A brightly coloured group of 'domes' on the western flank of Heart Peaks forms a prominent landmark that is visible for miles. Two local basalt domes underlie Heart Peaks to the east. During 1984, access to the property was by helicopter from either Dease Lake or Atlin. The writer visited the property on August 22 and 23. Kerr Addison Mines Ltd. conducted an eight-hole diamond-drill program under a joint venture agreement with Newmont in 1984. Work between 1980 and 1982 by the Newex Syndicate (Newmont, Lornex, and J. C. Stephen Ltd.) and during 1983 by Kerr Addison and Newmont discovered several precious metal anomalies in silicified and pyritized trachyte-rhyolite units and related breccias.

PROPERTY GEOLOGY

Most of the Hart claims are underlain by rhyolitic and trachytic lavas, tuffs, breccias, and by lower basalt flows (Heart Peaks Formation). The extreme eastern edge of the property is underlain by interlayered alkaline basalt flows (Level Mountain Group) which conformably overlie the Heart Peaks Formation. Heart Peaks Formation rocks are Pliocene in age; Level Mountain Group rocks are Plio-Pleistocene in age. The Heart Peaks basalt centre is part of an inferred line of centres which trends 030 degrees and includes Mount Edziza. Locally, trachyte domes show a less obvious north-northeast trend but probably lie along an old fracture system which controlled the location of late stage phreatic explosion breccias and associated vein mineralization.

The oldest rocks exposed on the property crop out in the western portion and consist of shales, siltstones, and sandstones of the Lower Jurassic Takwahoni Formation.

The Plio-Pleistocene volcanic rocks (Heart Peaks Formation) are comprised dominantly of three general lithologic types, which include in decreasing order of abundance; trachyte, basalt, and rhyolite. The trachytes form flows, domes and, locally, breccias. Fresh flows have a light grey, aphanitic matrix enclosing small light grey tabular phenocrysts of alkali feldspar, which comprise up to 20 per cent of the rock, and rare books of biotite and small rounded blebs of quartz; flow laminations are locally well developed. Pervasive silicification imparted a very dense hard character to the trachyte. Quartz veinlets and quartz-lined vugs are locally abundant.

The lower basalts are dark green to purple hawaiites with abundant lath-shaped 2 to 3-millimetre phenocrysts of plagioclase. The upper basalts are also hawaiites but contain large olivine crystals in addition to the phenocrysts of plagioclase. The rhyolites include massive to slightly flow foliated rocks along the sides of Tarfu Crater, southwest of Top Dome, west of Bug Basin, and underlying North Crater trachytes. Rhyolitic welded tuff (locally spherulitic) occurs locally, especially east of the main trachyte area, and on the east flank of Opal Dome. The stratigraphic positions of these various lithological units within the Heart Peaks Formation on the property is described in detail in *B.C. Ministry of Energy, Mines & Pet. Res.*, Assessment Report 11141.

A distinctive polymictic phreatic explosion breccia contains angular clasts of trachyte showing a wide variety of textures, as well as shale and siltstone clasts of the Takwahoni Formation and uncommon basalt clasts. The main exposures of breccia occur along a northerly trend from the Top Zone through to the Mogul Zone; perhaps they reflect a deep-seated structural control.

The Level Mountain Group consists of massive flows of dark grey to black, fine-grained basalt. Some contain vesicles or amygdules of aragonite or chalcedony. The thicker flows are porphyritic with plagioclase laths up to 75 millimetres in length. The Castle Ridge basalt member, characterized by its content of large olivine crystals and black glass fragments, conformably overlies the Heart Peaks Formation; north-northeasterly trending basalt dykes cut the Heart Peaks Formation.

STRUCTURE

Regionally, young volcanic centres occur in a northerly to north-northeasterly trend. Locally, trachyte domes show a more subtle north to north-northeasterly trend. A fracture system at 015 degrees, developed within the trachytes, may have controlled emplacement of late phreatic explosion breccias and associated vein mineralization. Basalt dykes with north to north-northeasterly trends probably fill fractures which opened during post-extrusive Plio-Pleistocene extension.

No obvious large scale faults have been observed on the surface.

ALTERATION

Three styles of alteration are observed: (1) pervasive silicification (±pyrite), (2) argillation, and (3) opalization.

Widespread silicification occurs in trachytes and explosion breccias associated with the Top, Mogul, Dog, and King Domes, as well as at the Quartz Hill and Steep Showings. These silicified rocks host all the exposed veining of potential economic interest. Altered host rocks consist primarily of quartz, K-feldspar, and minor pyrite. Textures in phreatic explosion breccias indicate multiple episodes of brecciation and silicification.

Argillic alteration occurred in many areas including South Dome, Dog Dome, and Opal Dome. Zones of phreatic breccias including the Steep, Quartz Hill, End, and Mogul Zones also have undergone post brecciation.

Opalization is most prominent at Opal Dome where grey opal replaces trachyte and trachyte breccia. Locally green patches and veinlets of tridymite with K-feldspar and kaolinite are common.

Secondary alteration products identified by X-ray techniques include:

(i) rozenite ($FeSO_4 \cdot 4H_2O$) (for example, DDH-83-1-45m) and melanterite ($FeSO_4 \cdot H_2O$) (for example, DDH-84-3-75m) occur as rare fracture linings in silicified trachyte. Melanterite is translucent green-blue in colour but partially dehydrates within a few days to rozenite which is colourless to white;

(ii) illite [$2K_2O \cdot 3(Mg, Fe)O \cdot 8(Al, Fe)_2O_3 \cdot 24SiO_2$] (for example, DDH-84-1-278m, DDH-84-3-190m) appears to be the dominant clay alteration mineral, predominantly after K-feldspar. It occurs as late stage fracture fillings and replaces feldspars;

(iii) scorodite ($FeAsO_4 \cdot 2H_2O$) (for example, DDH-84-4-102m), which is pale leek-green in colour, occurs as rare fracture coatings in silicified trachyte;

(iv) jarosite occurs as fracture fillings;

(v) tridymite, associated with K-feldspar and kaolinite, occurs as veinlets in the zone of opalization;

(vi) kaolinite occurs in trace amounts in clay altered zones.

MINERALIZATION

Mineralization, associated with banded and/or vuggy quartz and rare amethyst veins, occurs locally along a north to north-easterly trend from Top Dome (including Top Zone, Quartz Hill Zone), through the Steep Zone, to the End and Mogul Zones, a length of approximately 2 kilometres (Fig. 123). With the exception of the Top Zone, the quartz veining is intimately associated with the phreatic explosion breccia, cutting either it or adjacent silicified trachytes. Precious metals are associated with quartz veins in trachytes in silicified breccias, and in open space fillings. Except for minor amounts of local pyrite and rare arsenopyrite there are no base metals present. Pyrite is locally abundant (up to 20 per cent) within altered, silicified trachytes, and also replaces clasts in breccias. Minor stibnite-opal veining occurs near the Mogul Zone (Fred Daley, personal communication, 1984).

The Top Zone consists of an area approximately 100 metres by 200 metres of intensly silicified trachyte with crosscutting banded and vuggy quartz and minor amethyst veins. The veins trend east-northeasterly to northeasterly, nearly at right angles to the overall trend of mineralized zones. Visible ruby silver (pyrargyrite, Ag_3SbS_3) occurs as disseminations in very fine-grained clay-layers within well-banded quartz veins up to 1 metre in width. The highest assays received from grab samples with pyrargyrite taken by Kerr Addison were 31.5 grams per tonne (0.92 ounce per ton) gold and up to 345 grams per tonne silver. Four diamond-drill holes were completed in 1984 on the Top Zone (Fig. 123). Grab samples taken by the writer are shown in Table 1.

TABLE 1
GRAB SAMPLES OF ALTERED ROCKS FROM THE HEART PEAKS PROSPECT

	Sample Number	Description	Mineralized Zone	Au ppm	Ag ppm	Hg ppb	As ppm	Sb ppm
1.	HP-84-1	Banded and vuggy quartz vein with pyrargyrite	Top	0.7	400	78	<8	124
2.	HP-84-2	Banded quartz vein with crosscutting greyish silica veinlet with minor disseminated sulphides	Top	1.4	1408	190	<8	600
3.	HP-84-4	7.6-centimetre-wide coarse amethyst vein in silicified trachyte	Top	<0.3	<10	146	191	38
4.	HP-84-8	Grey chalcedonic trachyte breccia	Top	0.3	15	210	880	21
5.	HP-84-13	Banded white to blackish chalcedonic silica	Top	3.4	529	100	28	97
6.	HP-84-16	Silicified trachyte with quartz veinlets	Top	0.3	<10	544	102	8
7.	HP-84-17	Silicified trachyte with disseminated pyrite (5%)	Top	<0.3	<10	108	56	8
8.	HP-84-22	Silicified trachyte with disseminated pyrite (4%)	Quartz Hill	<0.3	<10	42	376	<3
9.	HP-84-24	Silicified trachyte breccia with disseminated pyrite (2%)	Quartz Hill	1.4	502	20	0.49%	29
10.	HP-84-26	Silicified trachyte breccia with quartz veinlets and argillized fragments	Quartz Hill	<0.3	<10	189	126	<3
11.	HP-84-36	Silicified breccia with pyrite	Dog	<0.3	<10	-	20	<3

The Quartz Hill Zone consists of open space filling, coarsely crystalline quartz veins within polymictic breccias and silicified trachytes. The veins show distinctive cockscomb and platy internal structures; individual quartz prisms are commonly zoned from clear interiors to milky white exteriors. The veins form stockwork mineralization with an average north to northwesterly trend. Two diamond-drill holes were drilled in 1984 on this zone (Fig. 123). Pyrite and trace arsenopyrite were the only sulphides observed. Grab samples taken by the writer are shown in Table 1.

The Steep Zone is hosted by a pyritic, silicified explosion breccia and blocks (?) of trachyte. Quartz veins up to 1 metre across trend north-northeasterly and north-northwesterly and exhibit cockscomb textures, with large euhedral quartz crystals ranging up to 5 centimetres in length, and platy replacement textures. Two drill holes were completed in 1984 on this zone (Fig. 123).

Other zones of interest include the Mogul Zone, where quartz veins cut explosion breccias and silicified trachytes with associated pyrite and minor stibnite, and the End Zone, where quartz veins cut explosion breccias.

WORK DONE

During 1984, Kerr Addison diamond drilled eight holes totalling 1972.3 metres - four on the Top zone, two on the Quartz Hill Zone, and two on the Steep Zone.

COMMENTS

Alteration and mineralization on the Heart Peaks property appears to have occurred at a very high level within an epithermal system. Features which indicate this include: the presence of opal; extensive development of silica±sinter; the presence of amethyst; low base metal content; anomalous amounts of arsenic, antimony, and mercury; cockscomb textures, including some double terminations of quartz crystals; development of large euhedral quartz crystals; good rhythmic banding of quartz veins; and common vuggy quartz veins. It should be noted, however, that the silver to gold ratio is very high relative to the hypothetical epithermal model. Phreatic explosion breccias, probably caused by massive steam eruptions, are located along a north-northeasterly trending zone of weakness (crustal extension?); they exhibit sharp contacts with altered trachytes. Significant quartz veining and associated precious metal mineralization occur in close spatial association with these breccias. Later circulation of magmatic and meteoric waters through the hot permeable zone may have given rise to the veining and related mineralization. The very young age of the host rocks and thus the mineralization (that is, younger than 4 Ma) is significant in terms of metallogenic models and future exploration targets.

ACKNOWLEDGMENTS

The writer would like to thank Kerr Addison Mines Ltd., and particularly Fred Daley, for logistical support, for access to the showings, and for their kind hospitality and openess while on the property.

REFERENCES

B.C. Ministry of Energy, Mines and Petroleum Resources: Assessment Reports 11141 and 11233.

Souther, J. G. (1971): Geology and Mineral Deposits of Tulsequah Map-Area, British Columbia, *Geol. Surv., Canada*, Mem. 362.

MINERAL OCCURRENCES IN THE MOUNT HENRY CLAY AREA
(114P/7, 8)

By D. G. MacIntyre and T. G. Schroeter

INTRODUCTION

Mineral occurrences in the Mount Henry Clay area were visited during a two-day period in early August as part of a continuing study of volcanic-hosted massive sulphide deposits of the Insular Tectonic Belt. This report summarizes what is known to date about the geology and mineral occurrences in the Mount Henry Clay area. Much of the information in this report is from unpublished reports supplied by the United States Bureau of Mines and Stryker-Freeport Resources.

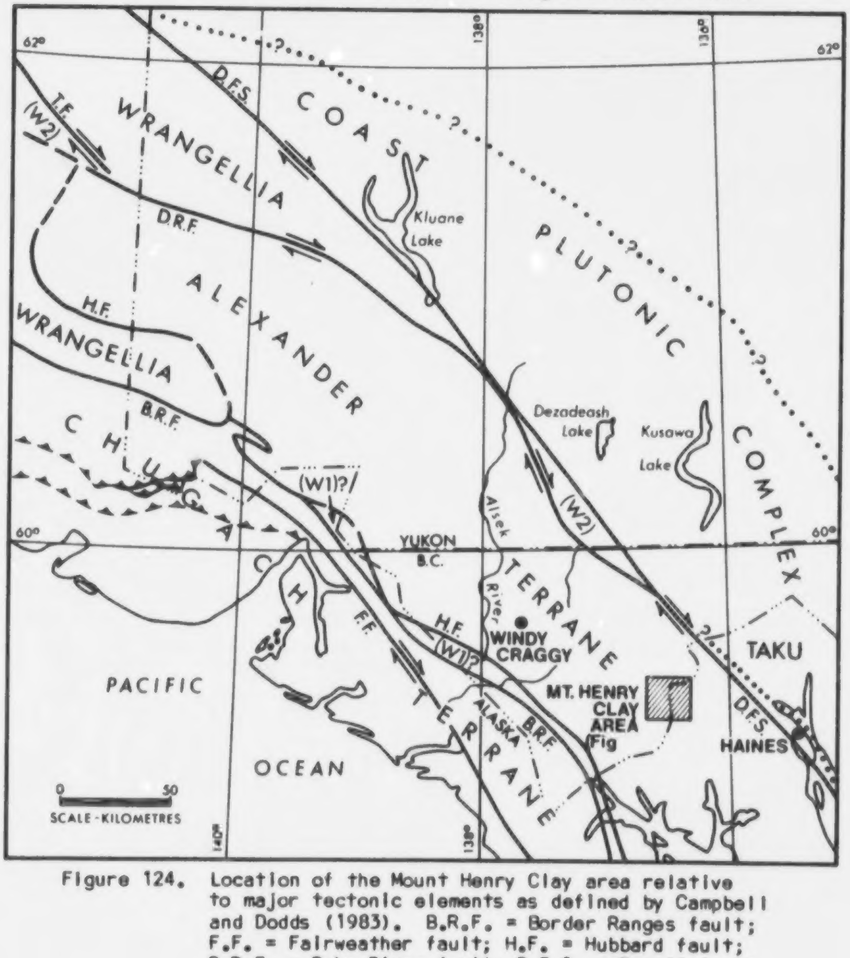

62°
138°
136°
62°
D.F.S.
?
COAST
PLUTONIC
COMPLEX
T.F.
(W2)
WRANGELLIA
D.R.F.
Kluane Lake
ALEXANDER
H.F.
WRANGELLIA
B.R.F.
CHUGACH
(W1)?
Dezadeash Lake
Kusawa Lake
Alsek River
(W2)
60°
60°
YUKON
B.C.
TERRANE
WINDY CRAGGY
TAKU
F.F.
H.F.
(W1)?
MT. HENRY CLAY AREA Fig
ALASKA
B.R.F.
D.F.S.
HAINES
PACIFIC
OCEAN
TERRANE
0 50
SCALE - KILOMETRES
140°
138°

Figure 124. Location of the Mount Henry Clay area relative to major tectonic elements as defined by Campbell and Dodds (1983). B.R.F. = Border Ranges fault; F.F. = Fairweather fault; H.F. = Hubbard fault; D.R.F. = Duke River fault; D.F.S. = Denali fault system; T.F. = Totschunda fault; W1 = Wrangellia.

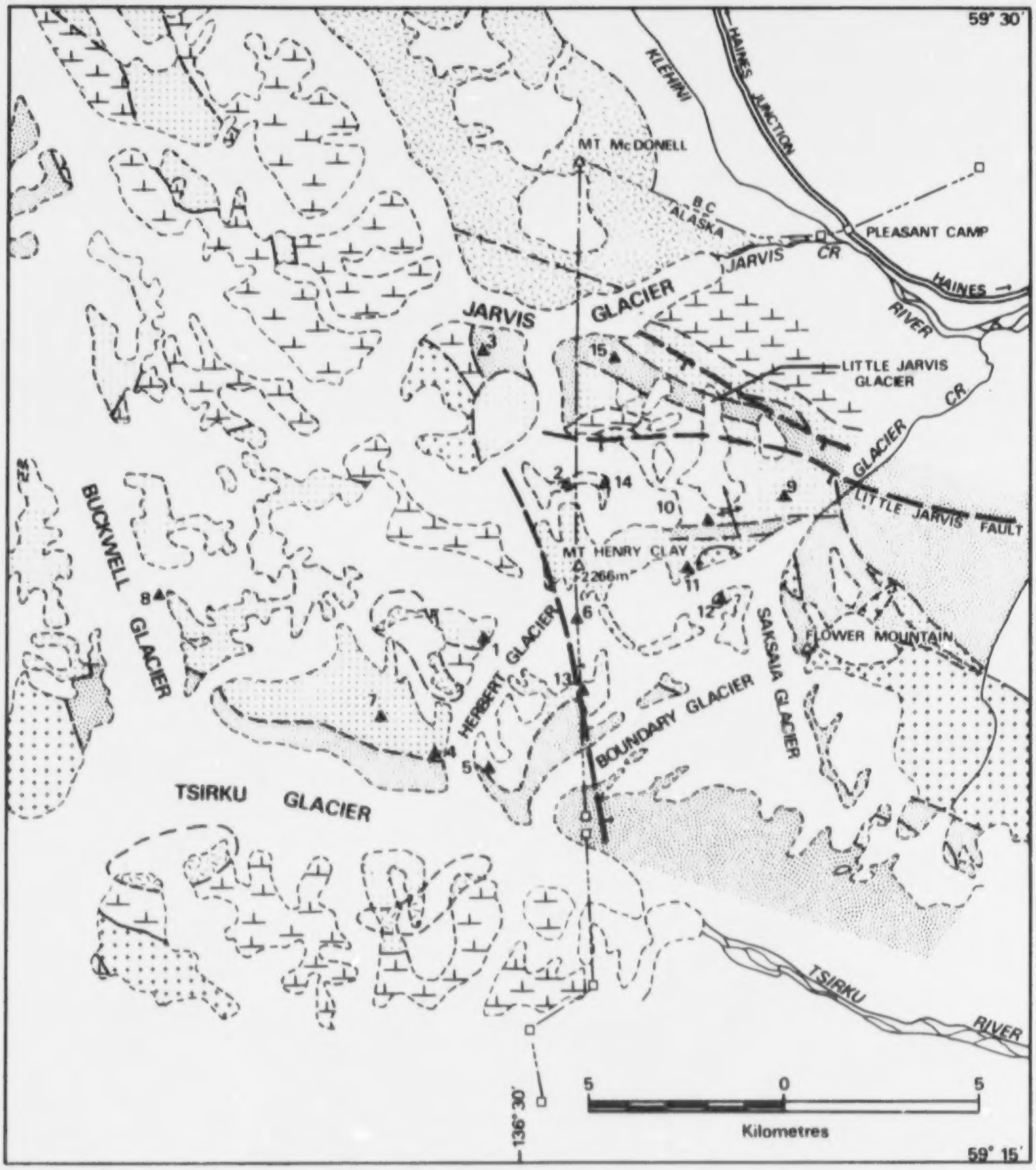

59° 30'
KLEHINI
HAINES JUNCTION
MT McDONELL
B.C
ALASKA
PLEASANT CAMP
JARVIS CR
HAINES →
RIVER
JARVIS GLACIER
3
15
LITTLE JARVIS GLACIER
CR
GLACIER
LITTLE JARVIS FAULT
2
14
10
9
MT HENRY CLAY
2266m
11
12
8
BUCKWELL GLACIER
6
1
HERBERT GLACIER
13
7
4
5
BOUNDARY GLACIER
SAKSAIA GLACIER
FLOWER MOUNTAIN
TSIRKU GLACIER
TSIRKU RIVER
5
0
5
Kilometres
136° 30'
59° 15'

Figure 125. General geology and location of mineral occurrences, Mount Henry Clay area. British Columbia geology after Campbell and Dodds (1983); Alaska geology after Redman (Still, 1984).

LEGEND

▨ **OLIGOCENE** – GRANITIC INTRUSION

+ **CRETACEOUS – TERTIARY**
HORNBLENDE GABBRO, DIORITE

▨ **PALEOZOIC AND/OR MESOZOIC**
MAFIC TO INTERMEDIATE FLOWS;
MINOR TUFFS, VOLCANICLASTICS

▨ **PALEOZOIC AND/OR MESOZOIC**
FINE-GRAINED CLASTIC ROCKS

⊥ **ORDOVICIAN TO DEVONIAN (?)**
LAMINATED CARBONATE AND LIMY
MUDSTONE, SILTSTONE; MASSIVE
FOSSILIFEROUS LIMESTONE

▲1 MINERAL OCCURRENCE (*see* TABLE 1)

MINERAL OCCURRENCES

BRITISH COLUMBIA

1 LOW HERBERT, Cu, Pb, (Ag, Au)
2 LOW JARVIS, Cu, (Ag)
3 HIGH JARVIS, Zn, (Ag, Au)
4 HERBERT MOUTH W., Au, Co, (Ag)
5 HERBERT MOUTH E., (Cu, Zn, Co, Ag)
6 HIGH HERBERT N., Cu, (Ag, Au)
7 GRIZZLY HEIGHTS, Au, (Ag)
8 BUCKWELL MORAINE, Cu

ALASKA

9 GLACIER CREEK – MAIN (HAINES Ba), Ba, Zn, Cu, Ag, (Pb)
10 GLACIER CREEK – HANGING GLACIER, Ba, Zn, Pb, Cu, Ag, (Au)
11 GLACIER CREEK – CUP, Ba, Zn, Pb, Ag, (Au)
12 GLACIER CREEK – NUNATAK, Ba, Ag, (Pb, Zn, Cu, Au)
13 BOUNDARY, Ba
14 MT. HENRY CLAY (BOULDERADO), Zn, Cu, Ag, (Pb)
15 JARVIS GLACIER, Zn, Cu, Ag, (Pb, Au)

LOCATION AND TOPOGRAPHY

Mount Henry Clay is located along the British Columbia-Alaska border (Fig. 124), 65 kilometres northwest of Haines, Alaska. The topography of the area is characterized by steep ice-carved ridges and peaks surrounded by valley and hanging glaciers. Access is via helicopter from the Haines Highway, located 10 kilometres northeast of Mount Henry Clay.

EXPLORATION ACTIVITY

Recent exploration work in the Mount Henry Clay area is largely the result of the discovery of the Windy-Craggy deposit (MacIntyre, 1983) located 75 kilometres to the northwest. During the 1984 field season the Stryker-Freeport Resources joint venture prospected their approximately 900 unit Jarvis-Tsirku claim group which covers the area west of Mount Henry Clay. The Tsirku claims were staked in 1983 to cover an area that appeared to be underlain by mafic volcanic rocks similar to those hosting the Windy-Craggy deposit. Work on the property has resulted in the discovery of several new showings, the most significant of which is the Low Herbert (Fig. 125).

In Alaska, several stratabound barite-sulphide occurrences were discovered in the vicinity of Glacier Creek as early as 1969. They are hosted by altered, foliated tuffs or sheared flows within a mafic

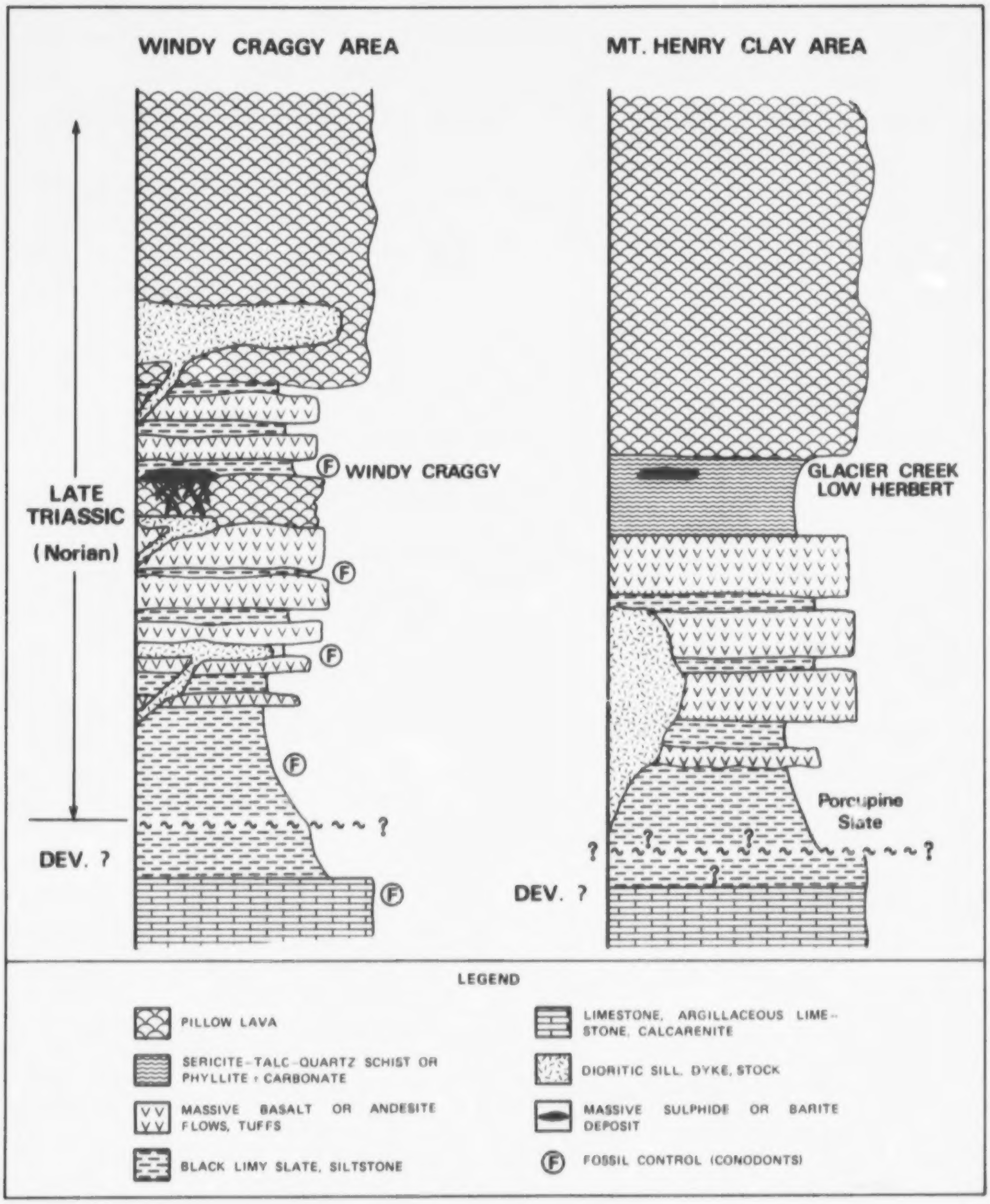

WINDY CRAGGY AREA
MT. HENRY CLAY AREA
LATE TRIASSIC
(Norian)
DEV. ?
WINDY CRAGGY
F
GLACIER CREEK
LOW HERBERT
Porcupine Slate
?
DEV. ?
LEGEND
PILLOW LAVA
SERICITE-TALC-QUARTZ SCHIST OR PHYLLITE ± CARBONATE
MASSIVE BASALT OR ANDESITE FLOWS, TUFFS
BLACK LIMY SLATE, SILTSTONE
LIMESTONE, ARGILLACEOUS LIMESTONE, CALCARENITE
DIORITIC SILL, DYKE, STOCK
MASSIVE SULPHIDE OR BARITE DEPOSIT
FOSSIL CONTROL (CONODONTS)

Figure 126. Generalized stratigraphic columns for the Windy-Craggy and Mount Henry Clay areas showing approximate position of mineral occurrences.

volcanic sequence. The most significant of these is the Haines Barite or Glacier Creek Main deposit. In 1983, renewed interest in the area resulted in the discovery of massive sulphide boulders on the north slope of Mount Henry Clay by ALYU Mining Corporation. In 1984, Bear Creek Mining Company diamond drilled this prospect.

GEOLOGIC SETTING

The geology of th. Tatshenshini map-area (114P) has been compiled at 1:125 000 scale by the Geological Survey of Canada (Campbell and Dodds, 1983). This work has shown that within the Alexander terrane, which is mainly a belt of Paleozoic basinal sedimentary rocks (Fig. 124), there are also areas underlain by mafic submarine flows and associated volcaniclastic rocks. Originally thought to also be Paleozoic in age, it has now been shown, in the Windy-Craggy area at least, that these submarine volcanic rocks are actually Late Triassic (Norian) and are preserved in downthrown fault blocks within the Paleozoic terrane (MacIntyre, 1984). These Late Triassic submarine volcanic rocks are host to significant stratiform copper-cobalt-zinc-gold deposits such as Windy-Craggy.

On cursory examination the stratigraphic sequence of the Mount Henry Clay area is similar to that of the Windy-Craggy area. In both areas fine-grained basinal clastic rocks are overlain by intermediate to mafic submarine flows (Fig. 126). The inference is that the rocks of the Mount Henry Clay area are also Late Triassic. Unfortunately there are no fossil or isotopic age dates from the Mount Henry Clay area to prove this hypothesis.

Similarly, mapping by E. Redman (Still, 1984) in Alaska indicates that the area east of Mount Henry Clay is predominantly fine-grained clastic rocks (Porcupine slate) overlain by mafic to intermediate submarine flows and intruded by Cretaceous hornblende diorite (Fig. 125). Limestone that contains abundant two-hole crinoid plates is exposed north of Mount Henry Clay and is most likely Devonian in age. The relationship of this unit to apparently underlying and overlying mafic volcanic sequences is uncertain. Originally thought to occupy the core of a synclinal structure, there is now some suggestion that the contacts with the adjacent mafic volcanic units may be high angle faults, with the mafic volcanic sequences being downthrown relative to the apparently Devonian age carbonates. If this relationship is real, and the mafic submarine volcanic rocks are in fact Late Triassic in age, then the Mount Henry Clay area is structurally and stratigraphically similar to the Windy-Craggy area. However, until good fossil or isotopic ages are obtained from these rocks all of these relationships are purely speculative.

MINERAL OCCURRENCES

Although there is gross stratigraphic similarity between the Windy-Craggy and Mount Henry Clay areas, the mineralogy of the presumably stratiform

TABLE 1

	MINERALOGY	TYPE	HOST
BRITISH COLUMBIA OCCURRENCES			
1 LOW HERBERT	Py, Cp, Sp, Ba, (Ag, Au)	Disseminated and banded	Sericite-talc schist
2 LOW JARVIS	Sp, Cp, Ba, (Ag)	Massive (float)	Pyritic felsic tuff or exhalite?
3 HIGH JARVIS	Py, Sp, (Ag, Au)	Massive	Limestone, siltstone, felsic tuff
4 HERBERT MOUTH WEST	Py, Au, Co, (Ag)	Disseminated and massive pods	Pyritic felsic tuff or volcaniclastics in pillow lavas
5 HERBERT MOUTH EAST	Py, Po, (Cp, Sp, Co, Ag)	Disseminated and massive	Andesitic volcaniclastic
6 HIGH HERBERT NORTH	Py, Cp, (Ag, Au)	Disseminated	Felsic to intermediate pyroclastic rocks
7 GRIZZLY HEIGHTS	Py, Po	Massive (float)	Unknown
	Qz, Po, Au, (Ag)	Vein	Sedimentary rocks (?)
8 BUCKWELL MORAINE	Cp, Py, Po, Co	Carbonaceous bands in float	Unknown – probably basalt
ALASKA OCCURRENCES			
9 GLACIER CREEK – MAIN (HAINES BARITE)	Ba, Sp, Cp, Ag, (Gl)	Bands in barite lenses	Carbonate-sericite altered schistose tuff
10 GLACIER CREEK – HANGING GLACIER	Ba, Py, Sp, Gl, Cp, Ag, (Au)	Barite lenses and veins	Pillow basalt
11 GLACIER CREEK – CAP	Ba, Ag, Py, Sp, Gl, Tt, (Au)	Bands in barite lenses	Andesite and basalt ?
12 GLACIER CREEK – NUNATAK	Ba, Ag, Py, (Gl, Sp, Cp, Au)	Barite lenses	Andesite and basalt
13 BOUNDARY	Ba	Barite lens	Altered phyllite ? or schist
14 MT. HENRY CLAY (BOULDERADO)	Sp, Py, Cp, Ag, Ba, (Gl)	Massive float	Chlorite-altered andesite and/or basalt
15 JARVIS GLACIER	Py, Sp, Cu, Ag, (Gl, Au)	Massive and disseminated	Chlorite-altered metasediments and andesites

NOTE: Minerals arranged in order of decreasing abundance or importance. Those in brackets present in minor to trace amounts. Py = pyrite; Cp = chalcopyrite; Sp = sphalerite; Gl = galena; Ba = barite; Po = pyrrhotite; Tt = tetrahedrite; Co = cobaltiferous, mineral phase unknown; Ag = argentiferous, mineral phase unknown; Au = auriferous.

Information on British Columbia occurrences from McDougall, *et al.*, 1983; Alaska occurrences from Still, 1984.

mineral occurrences in these two areas is quite different. Windy-Craggy is essentially a thick lens or series of lenses of massive pyrrhotite and/or pyrite with chalcopyrite, sphalerite, and magnetite-rich zones; it is underlain by chlorite-altered basalts with abundant sulphide stringers and overlain by interbedded limy siltstones and basaltic tuffs (Fig. 126). Mineral occurrences in the Mount Henry Clay area are typically barite rich with thin bands and disseminations of pyrite, pyrrhotite, sphalerite, chalcopyrite, and minor amounts of galena in locally siliceous, sericite-carbonate-talc-altered, foliated tuffs or sheared flows. The mineralized zones are typically underlain by massive andesitic flows with intercalated sedimentary rocks; they are overlain by relatively unaltered massive pillow lavas.

The following section briefly describes the major mineral occurrences in the Mount Henry Clay area. Information on the British Columbia occurrences is derived from an unpublished report by McDougall, *et al.* (1983) of Stryker Resources. The Alaskan occurrences are described in an unpublished report by Jan Still (1984) of the United States Bureau of Mines with appended reports by Earl Redman formerly of C. C. Hawley and Associates.

Location of occurrences is shown on Figure 125; the mineralogy and host rocks are summarized in Table 1. It should be noted that only the Low Herbert, Buckwell Moraine, Glacier Creek Main, and Mount Henry Clay occurrences were examined during our tour of the area. Information on the remaining occurrences is taken from the previously mentioned reports.

BRITISH COLUMBIA OCCURRENCES

Low Herbert (1)

The Low Herbert showing is located on the west side of the Herbert Glacier, within a bright yellow to orange gossanous zone that appears to parallel bedding. This zone, which locally is over 100 metres thick, can be traced for 700 metres along strike before being covered by ice. A thick sequence of pillow lava overlies the mineralized zone, which apparently has a moderate dip to the southwest.

The Low Herbert showing is comprised of bands of disseminated fine-grained pyrite, and lesser chalcopyrite, barite, and sphalerite in a foliated, siliceous, sericite-talc to chlorite-talc-altered tuff or sheared flow. Small white circular structures, which may be accretionary lapilli, are common. Locally the rock is intensely foliated and completely altered to sericite and clay with the foliation deflecting around angular clasts of a black siliceous rock (Plate IX). Chalcopyrite and sphalerite appear to be more abundant in the chlorite-altered parts of the zone. Analytical results for eight samples collected from the Low Herbert showing are summarized in Table 2 (Nos. 1 to 8).

TABLE 2
CHEMICAL ANALYSES*

	Au	Ag	Cu	Pb	Zn	Co	As	Sb
1	<0.3	<10	0.01	0.03	0.31	29	-	-
2	<0.3	<10	0.73	<0.01	0.07	104	-	-
3	<0.3	<10	1.17	<0.01	0.07	96	-	-
4	<0.3	14	0.02	0.01	0.32	36	-	-
5	<0.3	<10	0.49	<0.01	7.04	72	-	-
6	<0.3	<10	1.64	<0.01	0.18	90	-	-
7	<0.3	<10	0.18	<0.01	0.30	64	-	-
8	<0.3	<10	0.10	<0.01	6.46	34	-	-
9	<0.3	<10	2.51	0.03	0.09	1 500	-	-
10	<0.3	<10	0.25	0.01	0.02	1 300	-	-
11	0.7	23	1.27	0.50	15.2	23	174	111
12	0.7	60	0.44	3.60	32.3	<8	844	127
13	<0.3	22	1.12	0.29	36.0	23	767	93
14	0.7	62	1.03	0.22	40.1	29	844	107
15	0.7	10	0.30	0.05	13.4	38	384	29
16	0.7	<10	0.19	0.03	10.5	53	384	27

*Au, Ag, Co, As, Sb in ppm; Cu, Pb, Zn in per cent

1 - Low Herbert - north end of showing, highly bleached, altered tuff with disseminated barite and pyrite
2 - Low Herbert - disseminated chalcopyrite in altered accretionary lapilli (?) tuff
3 - Low Herbert - same as No. 2
4 - Low Herbert - north end of showing, bedded pyrite in altered tuff
5 - Low Herbert - altered tuff with pyrite, sphalerite, barite, and chalcopyrite
6 - Low Herbert - chalcopyrite and pyrite-rich band in altered tuff
7 - Low Herbert - pyrite-rich band in altered tuff
8 - Low Herbert - sphalerite-rich band in altered tuff
9 - Buckwell Moraine - massive pyrite, chalcopyrite float
10 - Buckwell Moraine - massive pyrite float
11-16 - Banded massive sphalerite, barite, pyrite, chalcopyrite, and galena from float from Mount Henry Clay (Boulderado) occurrence

NOTE: Samples 1 to 10 not analysed for As and Sb.

Low Jarvis (2)

The Low Jarvis showing is a rusty-weathering band of felsic, pyritic exhalite or tuff that underlies the thick basalt unit capping Mount Henry Clay. The showing is immediately east of the area drilled by Bear Creek Mining Company.

High Jarvis (3)

The High Jarvis showing is on the steep north-facing slope of an unnamed peak that is located south of the main arm of the Jarvis Glacier. McDougall, *et al.* (1983) describe the showing as a stratiform band

Plate IX. Dark clasts in pervasively altered and foliated tuff, Low Herbert showing.

of massive pyrite and sphalerite occurring in a limestone, silty limestone, siltstone, and felsic tuff sequence. These rocks may be part of the Paleozoic succession.

Herbert Mouth West (4)

This showing is located on the west side of Herbert Glacier, close to its confluence with Tsirku Glacier. [illegible] described as a near vertical zone of pyritic volcaniclastic rocks with local pods of massive pyrite that occurs near the base of a thick pillow lava sequence. A sample of massive pyrrhotite float is reported to have assayed '0.466 ounce per ton gold, 0.129 per cent cobalt with 0.32 ounce per ton silver' (McDougall, *et al.*, 1983, p. 27). These values, if correct, are similar to those obtained from parts of the Windy-Craggy deposit.

Herbert Mouth East (5)

This showing is located near ice level on the east side of Herbert Glacier, close to its junction with Tsirku Glacier. McDougall, *et al.* (1983) describe the showing as pyrite, pyrrhotite, with lesser chalcopyrite and sphalerite in an andesitic volcaniclastic rock. These rocks are part of a large lens of sedimentary and pyroclastic rocks enclosed in unaltered pillow lavas.

High Herbert North (6)

This showing occurs in a saddle on the ridge that extends south from Mount Henry Clay. Disseminated and fracture-controlled pyrite and chalcopyrite are found in a light green andesitic tuff. These rocks are part of a pyroclastic unit that apparently underlies the thick pillow lava sequence which caps Mount Henry Clay. Galena occurs in quartz veinlets and stringers cutting chert beds.

Grizzly Heights (7)

Boulders of massive pyrrhotite and pyrite are reported to occur on the south-facing slope of the ridge between Herbert and Buckwell Glaciers. These boulders apparently occur down slope from the contact between sedimentary rocks and overlying pillow lavas. McDougall, *et al.* (1983) also describe a small quartz vein that contained '0.344 ounce per ton gold and 0.42 ounce per ton silver.'

Buckwell Moraine (8)

Boulders with bands of massive chalcopyrite, pyrite, and pyrrhotite in a quartz and/or carbonate-rich host have been found on a lateral moraine emanating from an eastern tributary of Buckwell Glacier. The source of these boulders has not yet been located. Analytical results for two samples of mineralized float collected from the moraine are summarized in Table 2 (Nos. 9 and 10).

ALASKAN OCCURRENCES

Glacier Creek Main (Haines Barite) (9)

The Glacier Creek Main or Haines Barite is the most economically significant deposit known in the Mount Henry Clay area to date. This deposit is located on a steep southeast-facing slope on the north side of Glacier Creek. The Cap, Hanging Glacier, and Nunatak showings are also considered part of the Glacier Creek occurrence. All of these deposits are hosted by the Glacier Creek sequence of submarine basalt, andesite, and fine-grained clastic rocks (Porcupine slate).

The Main deposit is contained within a steep northeast-dipping zone of foliated and pervasively sericitized tuffs or sheared flows. It has a strike length of approximately 600 metres and is up to several tens of metres thick (Plate X). Within this zone are beds or lenses of massive barite that locally contain bands of sphalerite, galena, and chalcopyrite. The mineralized zone is overlain by massive pillow lavas; it is underlain by andesitic to basaltic flows with intercalated sedimentary rocks. Still (1984) reports that a bulk sample collected from the deposit contained '76.4 per cent $BaSO_4$, 3.6 per cent zinc, 0.98 per cent copper, 0.12 per cent lead, and 92 ppm silver.' Geological reserves are estimated to be 3 to 4 million tons, although only one of three drill holes completed to date has intersected the deposit.

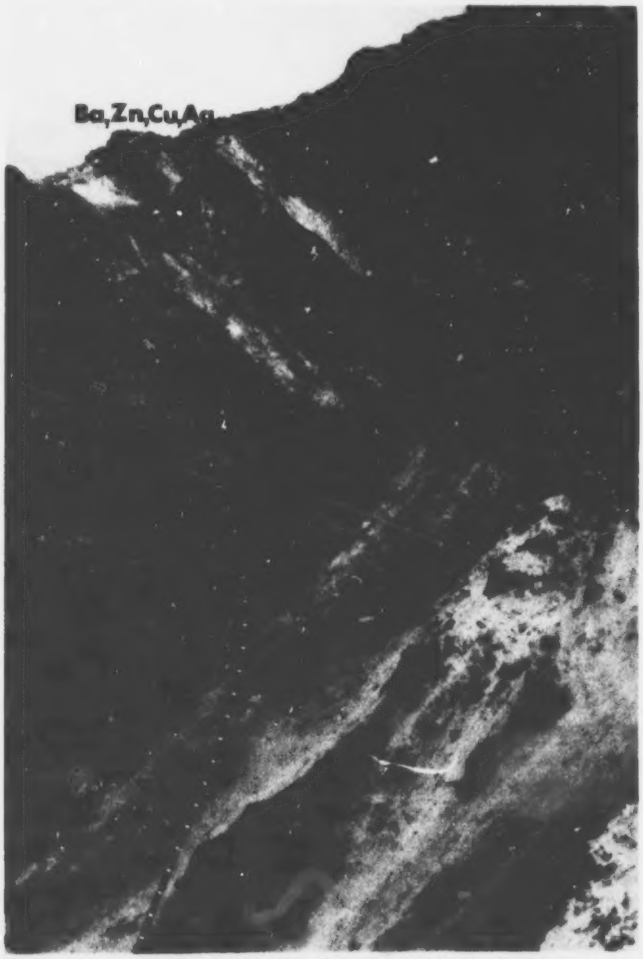


Plate X. View of the Glacier Creek Main (Haines Barite) deposit. Dashed line outlines zone of pervasively altered and foliated tuff that contains barite-sulphide lenses. Zone is overlain and underlain by massive basaltic flows.

Glacier Creek - Hanging Glacier (10)

The Hanging Glacier occurrence consists of barite lenses and quartz-carbonate veins that contain pyrite, sphalerite, galena, and chalcopyrite with anomalous silver and gold values. The barite lenses occur in a steep northwest-dipping gossan zone that underlies massive pillow lavas.

Glacier Creek - Cap (11)

The Cap occurrence is a barite lens up to 3 metres thick that contains pyrite, sphalerite, galena, and tetrahedrite. Like the other Glacier Creek occurrences, it is contained within a gossanous zone that is overlain by massive basaltic flows. Although base metal values are relatively low, Still (1984) reports silver assays as high as 277 ppm.

Glacier Creek - Nunatak (12)

The Nunatak occurrence is a steeply southwest-dipping barite bed or lens, up to 1 metre thick, that contains up to 19 ppm silver and 0.24 ppm gold (Still, 1984) despite relatively low lead, zinc, and copper. The host rocks are mainly andesite and basalt flows, similar to those hosting the other Glacier Creek occurrences.

Boundary (13)

The Boundary occurrence is located on the crest of the ridge extending south from Mount Henry Clay; it is close to or on the British Columbia-Alaska border. The occurrence is a 20-centimetre-thick bed or lens of barite with low metal values that is hosted by foliated volcanic rocks or phyllites. These rocks occur at the transition from Porcupine slate to overlying massive intermediate to basaltic flows.

Mount Henry Clay (Boulderado) (14)

Rounded to angular boulders and blocks of massive sphalerite, with bands of barite, pyrite, and chalcopyrite occur on the north-facing slope of Mount Henry Clay, just below the terminus of a small hanging glacier and very close to the Alaska-British Columbia border (Plate XI). Bear Creek Mining Company drilled two holes upslope from this showing in an attempt to locate the source of the boulders. This work and surface mapping indicates that the area of interest is largely underlain by massive andesitic flows that are locally altered and mineralized. This andesitic unit apparently dips southwest and is overlain by the massive pillow lavas that cap Mount Henry Clay. The only outcrop in the vicinity of the massive sulphide boulders is a southwest-dipping, foliated chloritic flow or tuff that contains disseminated pyrite. This type of alteration and sulphide mineralization is very similar to that found in the stratigraphic footwall of the Windy-Craggy deposit.

Still (1984) reports that massive sulphide boulders from the Mount Henry Clay (Boulderado) occurrence 'contain from 20 per cent to 44 per cent zinc, about 5 per cent barium, and several per cent of copper.' Analytical results for six samples of massive sulphide collected during our visit to this occurrence are summarized in Table 2 (Nos. 11 to 16). Silver values for these samples range from less than 10 to 62 ppm; gold is only slightly anomalous with values up to 0.7 ppm.

MT HENRY CLAY

Plate XI. View of Mount Henry Clay looking south. White circles indicate area of massive sulphide float. Dashed line is approximate location of Alaska-British Columbia boundary.

Jarvis Glacier (15)

Several occurrences of stratabound sphalerite, pyrite, chalcopyrite, galena, and barite occur on the north-facing slope above Jarvis Glacier. The host rocks are part of a unit of interbedded slate, limestone, and andesite that is capped by massive andesitic flows and basaltic pillow lavas. Still (1984) reports that the massive sulphide lenses occur within a zone of chloritic metasedimentary rocks and are associated with quartz and calcite-rich bands. Samples of massive sulphide contained up to '17.8 per cent zinc, 0.3 per cent lead, 1.3 per cent copper, 0.163 ppm gold, and 11.56 ppm silver' (Still, 1984, p. 11).

SUMMARY

The following conclusions appear to be valid based on the limited amount of data available to date:

(1) There is a gross similarity in the stratigraphic position of mineral occurrences in the Windy-Craggy and Mount Henry Clay areas. However, the age of the host rocks in the two areas may be different.

(2) The immediate host rocks for stratabound barite-sulphide deposits of the Mount Henry Clay area are probably tuffs or sheared flows rather than pillow lavas.

(3) Host rocks in the Mount Henry Clay area are generally foliated and contain more sericite, talc, and quartz, and less stringer sulphide and chlorite alteration than those at Windy-Craggy.

(4) The mineral occurrences in the Mount Henry Clay area contain more barite and sphalerite, and less pyrrhotite, chalcopyrite, and magnetite than those of the Windy-Craggy area.

(5) Massive sulphide occurrences in the Mount Henry Clay area generally have lower cobalt concentrations than those of the Windy-Craggy area. Exceptions to this are the Herbert Mount West and Buckwell Moraine showings.

These differences in mineralogy and nature of host rock alteration and composition between the Windy-Craggy and Mount Henry Clay areas suggests different environments of formation. As pointed out by Finlow-Bates (1980), temperature is the most important controlling factor on the mineralogy of submarine massive sulphide deposits. This concept is illustrated on Figure 127. The barite-rich, pyrrhotite-deficient deposits

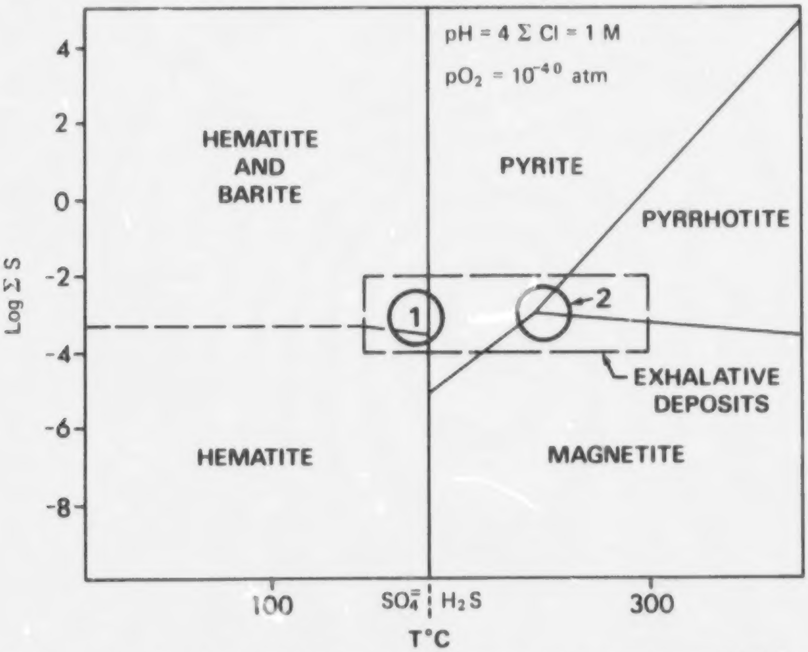


Figure 127. Stability fields of phases common in submarine exhalative deposits when formed from a solution with total Cl^{-} = 1M; pO_2 = 10 atm; pH = 4. Diagram from Finlow-Bates (1980). Circles represent hypothetical fields of formation based on the mineralogy of mineral occurrences in the Mount Henry Clay (circle 1) and Windy-Craggy (circle 2) areas.

of the Mount Henry Clay area may have formed at lower temperatures than the pyrrhotite-pyrite-rich, barite-deficient Windy-Craggy deposit. Also, the association of sericite, talc, carbonate, and quartz with the Mount Henry Clay occurrences may indicate boiling of hydrothermal fluids has taken place. Lower fluid temperatures and boiling suggest shallower water and/or a more vent-distal site of mineral deposition in the Mount Henry Clay area.

ACKNOWLEDGMENTS

The authors are most grateful to Stryker Resources and Bear Creek Mining Company for permission to visit their respective properties, for their most generous hospitality, and for the free exchange of geologic information and ideas. Discussions with Doug Perkins of Stryker Resources, Jan Still of the United States Bureau of Mines, Dan Rosenkrans and Rich Leveille of Bear Creek Mining Company, and Bruce Hickok of C. C. Hawley and Associates were most informative and helpful in assessing the area.

REFERENCES

Campbell, R. B. and Dodds, C. J. (1983): Geology, Tatshenshini Map-area (114P), *Geol. Surv., Canada,* Open File 926.

Finlow-Bates, T. (1980): The Chemical and Physical Controls on the Genesis of Submarine Exhalative Orebodies and their Implications for Formulating Exploration Concepts - A Review, *Geol. Jb.,* Vol. 40, pp. 131-168.

MacIntyre, D. G. (1983): A Comparison of Stratiform Massive Sulphide Deposits of the Gataga District with the Midway and Windy-Craggy Deposits, Northern British Columbia, *B.C. Ministry of Energy, Mines & Pet. Res.,* Geological Fieldwork, 1982, Paper 1983-1, pp. 149-170.

.... (1984): Geology of the Alsek-Tatshenshini Rivers Area (114P), *B.C. Ministry of Energy, Mines & Pet. Res.,* Geological Fieldwork, 1983, Paper 1984-1, pp. 173-184.

McDougall, J., Perkins, D., and Galatiotis, A. (1983): Geological Report of the Tsirku Group Mineral Claims, *Stryker Resources,* private rept., November 1983, 34 pp.

Still, J. (1984): Stratiform Massive Sulfide Deposits of the Mount Henry Clay Area, Southeast Alaska, *U.S. Bur. Mines,* Alaska Field Operations Center, Juneau, Alaska.

TABLE 1
TITANIA CONTENT OF TAILINGS FROM SELECTED PORPHYRY DEPOSITS IN BRITISH COLUMBIA

No.	Deposit Name	No. of Samples	Titania Analyses (%)		
			Range	Mean	Standard Deviation
A. Calc-alkaline suite porphyry copper deposits					
1	Bell	10	0.34-0.64	0.49	0.08
2	Bethlehem	2	0.35-0.43	0.39	0.06
3	Brenda	7	0.30-0.43	0.38	0.06
4	Gilbraltar	5	0.43-0.43	0.43	0.00
5	Granisle	8	0.40-0.78	0.56	0.13
6	Highmont	7	0.30-0.43	0.31	0.05
7	Island Copper	6	0.49-0.87	0.57	0.15
8	Lornex	12	0.30-0.43	0.35	0.05
Group		8		0.435	0.096
B. Alkaline suite porphyry deposits					
9	Afton	8	0.54-0.68	0.62	0.05
10	Granby	2	0.51-0.61	0.56	0.08
11	Newmont	9	0.33-0.97	0.67	0.21
	(i) Ingerbelle	6	0.52-0.97	0.77	0.15
	(ii) Copper Mtn.	3	0.33-0.53	0.44	0.10
Group		3		0.617	0.055
C. Porphyry molybdenite deposits					
12	Boss Mountain	2	0.35-0.43	0.39	0.06
13	Kitsault	4	0.49-0.57	0.56	0.04
Group		2		0.475	0.120
D. Others					
14	Equity Silver	4	0.81-0.97	0.84	0.08

TITANIUM IN TAILINGS OF PORPHYRY DEPOSITS IN BRITISH COLUMBIA

By Z. D. Hora and Y.T.J. Kwong

INTRODUCTION

Rutile, ilmenite, and, to a lesser degree, sphene are the most common minerals of titanium. Among these minerals, rutile is the preferred raw material for manufacturing titanium dioxide pigment and is practically essential for making titanium metal, which is heavily used in the aerospace industry. Recent studies on alternative sources of titanium in the United States (for example, Force, 1976; Force *et al.*, 1979; Llewellyn and Sullivan, 1980) suggest that porphyry deposits are potential hosts of titanium minerals as a by-product. To assess the titanium potential of similar deposits in British Columbia, a systematic examination of tailings from porphyry-type mines was initiated in the fall of 1982. Fourteen mines were chosen for an exploratory study that involved chemical determination of titania for the whole sample suite, mineralogical study of selected high-titanium samples by X-ray diffraction, and limited work on mineral separation and recovery. The main purposes of the study are to identify deposits of potential interest and to suggest areas and methods of further study where appropriate.

RESULT AND INTERPRETATION

Table 1 lists results of titania analyses, mainly by an emission spectrographic method from three main groups of porphyry deposits, namely (A) calc-alkaline suite porphyry copper deposits, (B) alkaline suite porphyry copper deposits, and (C) porphyry molybdenum deposits (calc-alkaline). The Equity Silver deposit shows a different style of mineralization compared to the previously mentioned deposits; it is therefore listed separately as Group D. From the table, it is evident that calc-alkaline porphyry deposits (Groups A and C) are lower in titania than the alkaline deposits (Group B) while Equity Silver (Group D) contains the most titania among the four groups. Using an arbitrary cutoff value of 0.50 per cent TiO_2, selected samples from promising deposits in each group were examined in more detail, both analytically and mineralogically. The findings are summarized in the following.

CALC-ALKALINE SUITE PORPHYRY COPPER DEPOSITS

Bell Copper

Chemical analyses by atomic absorption sepctroscopy indicate that titanium in the 10 samples from the deposit range from 0.39 to 0.73 per cent with an average of 0.55±0.09 per cent TiO_2. The major mineral constituents of the most titanium-rich sample (0.73 per cent TiO_2) are, in order of decreasing abundance, plagioclase, quartz, mica (biotite + muscovite $\leqslant$10 weight per cent), K-feldspar, chlorite with or without kaolinite, dolomite, siderite, pyrite, hematite, and calcite. Another sample with similar mineralogy but about half as much mica yielded 0.60 per cent TiO_2, indicating that the biotite is probably titaniferous. However, using the upper limits of titania content of various minerals listed in Table 2 and assuming that the first sample contains 2 weight per cent chlorite, 10 weight per cent biotite, and 0.5 weight per cent magnetite, a mass balance calculation accounts for titania content of 0.5 per cent; therefore about 0.2 per cent of finely disseminated rutile is suspected to be present. This amount of rutile is, however, not readily recoverable.

TABLE 2
TITANIA CONTENT OF COMMON TITANIUM-CONTAINING MINERALS
(Data source: Deer, 1966)

Mineral Name	Formula	TiO_2 per cent
Rutile	TiO_2	100
Anatase (+ brookite)	TiO_2	100
Leucoxene*	TiO_2	100
Sphene (titanite)	$CaTiO(SiO_4)$	40.8
Ilmenite	$FeTiO_3$	52.65
Ulvospinel	$FeTiO_4$	35.7
Magnetite	Fe_3O_4	<1.5
Biotite	$K(Mg, Fe)_3(AlSi_3O_{10})(OH)_2$	<5
Hornblende	$(Na,Ca)_{2-3}(Mg,Fe,Al)_5Si_6(Si,Al)_2O_{22}(OH)_2$	0.03-7.12, generally <2**
Clinopyroxene	$(Ca,Na)(Mg,Fe,Al)(Si,Al_2)O_6$	0.04-1.18, generally <0.8**
Chlorite	$(Mg,Al,Fe)_{12}[(Si,Al)_8O_{20}](OH)_{16}$	0.00-0.88, generally <0.35**

NOTES:

*Leucoxene is normally finely crystalline rutile (Deer, 1966). However, the same term has been loosely used elsewhere to include a mixture consisting mostly of rutile and partly of anatase or sphene (Glossary of Geology, American Geological Institute) and amorphous titanium dioxide (Kerr, 1959, p. 196). In this report, the first definition is adopted.

**Value used in the mass balance calculations unless otherwise stated.

A sub-sample was taken and the 80 to 100 mesh portion used for further testing. This sub-sample has a size distribution of 54.2 per cent >80 mesh, 9.9 per cent 80 to 100 mesh, and 35.8 per cent <100 mesh; 1.15 weight per cent of the sub-sample has a specific gravity exceeding 3.3.

This heavy fraction consists mainly of pyrite with lesser hematite and minor amounts of magnetite, siderite, dolomite, mica, K-feldspar, and quartz. No rutile was detected. Although K-feldspar might have masked its strongest reflection peak in the diffractogram, the detection of 0.73 per cent TiO_2 in the light fraction (S.G. <3.3) argues against any significant concentration of titania in the heavy fraction. Incidentally, the minus 100 mesh portion of the sub-sample is characterized by 0.79 per cent TiO_2, indicating that rutile, if present, is slightly enriched in the finest portion. Unfortunately, surface tension problems encountered in mineral separation involving heavy liquids and lack of facility for alternative methods of separation available in the laboratory prevented detailed analyses of the fine fraction.

Granisle

Atomic absorption analysis of the eight tailing samples gave a range of 0.44 to 0.88 per cent and a mean of 0.69±0.14 per cent TiO_2. The major mineral components are quartz, plagioclase, and biotite; minor to accessory phases identified include muscovite, K-feldspar, chlorite, calcite, magnetite, pyrite, gypsum, apatite, and hematite. The 80 to 100 mesh size fraction of a sample with 0.75 per cent TiO_2 was separated into two portions using heavy liquids. The heavy portion (S.G. >3.3), which makes up only 1.8 per cent of the sub-sample, contains a small amount of marcasite, chalcopyrite, and molybdenite in addition to the minerals mentioned previously. The titania content of this heavy portion is 1.26 per cent, considerably higher than the 0.73 per cent of the light portion (S.G. <3.3). Whereas rutile has not been positively identified in either, the mineralogy of various sub-samples and a mass balance calculation similar to that done for Bell Copper suggest that the original sample might contain up to 0.4 per cent free rutile. The biotite is, again, likely to be slightly titaniferous.

Island Copper

The mineral components of the six samples from the deposit include quartz, plagioclase, chlorite, calcite, muscovite, and minor amounts of pyrite, magnetite, laumonite with or without pyrophyllite, amphibole, and rutile. The size distribution and titania contents of a composite sample are listed in Table 3. A heavy liquid separation of the 80 to 100-mesh size fraction of a larger composite sample yielded 0.82 weight per cent of material with S.G. exceeding 3.3. Minerals identified from this heavy fraction are pyrite, magnetite, and minor amounts of quartz, chlorite, chalcopyrite, molybdenite, mica, plagioclase, and rutile. The predominating light fraction (S.G. <3.3) still contains 0.65 per cent TiO_2. It is estimated that the original sample might contain 0.45 per cent rutile.

TABLE 3

DISTRIBUTION OF TiO_2 IN VARIOUS SIZE-FRACTIONS (WEIGHT % IN BRACKETS) OF TAILINGS FROM SELECTED PORPHYRY DEPOSITS

Deposit Name	Bulk Sample	Titania Analyses (%)		
		>100 mesh	100-250 mesh	<250 mesh
A. Island Copper	0.64	0.61 (18.4)	0.62 (27.5)	0.67 (54.1)
B. Ingerbelle	0.73	0.66 (25.2)	0.68 (31.4)	0.81 (43.4)
C. Kitsault	0.67	0.61 (34.7)	0.62 (29.0)	0.75 (36.3)
D. Equity Silver	1.25	1.22 (16.4)	1.25 (39.1)	1.27 (44.5)

ALKALINE SUITE PORPHYRY DEPOSITS

Afton

Analyses of eight tailing samples by atomic absorption spectroscopy show a range of 0.60 to 0.75 per cent TiO_2 and an arithmetic mean of 0.70±0.05 per cent titania. The tailings consist of plagioclase, quartz, K-feldspar, calcite, chlorite, hematite, magnetite, mica (illite and minor amounts of biotite and muscovite), ankerite, native copper, chalcocite with or without epidote, clinopyroxene, and apatite. In addition, sphene occurs in many thin sections cut from specimens collected from the deposit and its vicinity. Electron microprobe analyses on magnetite (Cann, 1979) and silicate minerals (Kwong, 1980, unpublished data) from the deposit give the following data on titania content: magnetite 0.03 to 3.37 per cent; biotite, 5.37 to 6.83 per cent; clinopyroxene, 0.35 per cent; hornblende, 2.65 to 3.10 per cent; chlorite, 0.04 to 0.23 per cent; and epidote, 0.01 to 0.02 per cent. Based on these data and mineralogical analyses of various size and gravity fractions of a composite sample, it is concluded that the bulk of titania in the tailings is locked up in these minerals and sphene. Free rutile is estimated to be approximately 0.1 per cent.

Granby

The two samples collected outside of Princeton from the old Granby mines' operation yielded 0.57 and 0.69 per cent TiO_2 respectively. The sample with higher titania was found to consist of plagioclase, K-feldspar, biotite, quartz, clinopyroxene, chlorite, calcite, and minor amounts of hornblende, magnetite, and pyrite with or without ilmenite. The heavy fraction from the 80 to 100 mesh fraction of a subsample contains 1.2 weight per cent of the sample. This heavy mineral separate contains 5.97 per cent TiO_2 and consists of clinopyroxene, magnetite, sphene (5 to 8 per cent), pyrite, and minor amounts of ilmenite (about 2 per cent), chalcopyrite, rutile (about 2 per cent), chlorite, plagioclase, quartz, biotite, hornblende, and epidote and rare K-feldspar. Titanium minerals readily account for the titania content of the bulk sample. However, the relatively high concentration of titania in the heavy separate accounts for only about 10 per cent of the total titania content of the size fraction analysed. The rest is probably incorporated in very fine-grained titanium minerals that are associated closely with lighter grains that escaped separation.

Newmont

Since tailings from the Ingerbelle orebody are significantly higher in titania than those from the Copper Mountain orebody, only selected Ingerbelle samples were investigated in more detail. Mineralogically, the prominent components are plagioclase, augite, chlorite, biotite with or without minor muscovite, calcite, prehnite, gypsum, quartz, K-feldspar, magnetite, and pyrite with uncommon epidote, sphene, and ilmenite. The size distribution of a sample with 0.73 per cent TiO_2, together with the titania content of the various fractions, is listed in Table 3. Among the six samples examined, variation in titania content appears to depend on the abundance and/or presence of sphene, ilmenite, magnetite, biotite, and, to a lesser degree, augite. Material from the 60 to 80 mesh fraction with S.G. greater than 3.3 separated from a sample with 0.59 per cent TiO_2 is void of detectable rutile, ilmenite, and sphene. The titania in the sample probably occurs in biotite, magnetite, and possibly augite. As at Afton, rutile does not seem to occur in recoverable amounts.

PORPHYRY MOLYBDENUM DEPOSITS

Kitsault

Minerals determined in the four samples of the deposit include quartz, K-feldspar, plagioclase, mica (muscovite>>biotite), chlorite, calcite, dolomite, and trace amounts of amphibole, apatite, and molybdenite. The titania contents of various size fractions of a sample with 0.67 per cent TiO_2 are shown in Table 3. The heavy portion of the 60 to 100 mesh fraction of a composite sample with 0.63 per cent TiO_2 yielded 0.9 weight per cent of material. This heavy separate consists mainly of pyrite, some quartz and K-feldspar, and minor amounts of molybdenite and pyrrhotite with or without chalcopyrite. The light portion (S.G. <3.3) contains 0.57 per cent TiO_2 and consists of quartz, K-feldspar, plagioclase, lesser amounts of mica (mainly muscovite), calcite, chlorite, and trace amounts of pyrite and dolomite. Since no prominent titanium host minerals have been detected, it is suggested that TiO_2 in the composite sample occurs mainly as minute, finely dispersed grains of rutile. Unfortunately the reflection peaks of rutile are masked by those of K-feldspar in X-ray diffractograms so this conclusion cannot be confirmed.

OTHER DEPOSITS

Equity Silver

A sample of the Main zone final tailings from the pilot plant was reanalysed by X-ray fluorescence (XRF) and atomic absorption methods which gave 1.25 and 1.20 per cent TiO_2 respectively. The titania contents of various size fractions according to XRF analyses are shown in Table 3. Minerals identified from individual fractions include quartz, muscovite with some illite, plagioclase, chlorite, dolomite, calcite with or without chalcopyrite, magnetite, K-feldspar, and minor amounts of rutile and sphene, as well as pyrite, arsenopyrite, and galena. Magnetite is absent in a composite sample made up of three samples from the flotation tailings of the Southern Tail zone. The heavy portion of the 60 to 100 mesh fraction of this composite consists mainly of pyrite with small amounts of arsenopyrite and quartz. The light portion makes up 97.5 weight per cent of the size fraction and contains 0.99 per cent TiO_2. Its mineralogical composition is characterized by quartz, muscovite with some illite, plagioclase, and trace amounts of pyrite, arsenopyrite, rutile, chlorite, and kaolinite. Although minor amounts of titania may be locked up in magnetite and chlorite in the Main zone tailings, rutile is believed to account for the greater proportion of the contained titania.

DISCUSSION AND CONCLUSION

Limited by the facilities available and the sensitivities of the instruments used, some of the data presented above are semi-quantitative in nature. For example, in the mineralogical analyses, minerals present in amounts less than 2 per cent generally could not be identified positively. Pre-concentration techniques (for example, by panning or heavy liquid separation) can aid detection of minerals. However, where interference in X-ray diffraction patterns occurs, mineral abundances must be assessed from indirect evidence. In the present case, estimation of rutile occurring together with K-feldspar is particularly difficult. Nonetheless, the apparent consistency of data within each group allows valid comments to be made on the form and abundance of titaniferous minerals in the tailings and on the feasibility of recovering these minerals as a viable by-product.

Alkaline porphyry deposits contain more titania than calc-alkaline suite deposits. In these alkalic deposits, however, most titania is incorporated in silicates like biotite and hornblende and in less desirable titanium minerals like sphene and ilmenite. In contrast, most of the deposits in the calc-alkaline category appear to have more than half of their titania content in rutile (which should easily be confirmed by electron microprobe analysis). Among the remaining calc-alkaline deposits, which have less than 0.50 per cent titania, rutile has been reported in Bethlehem, Highmont, Brenda, and Boss Mountain (Drummond and Godwin, 1976).

From examination of tailings from the eight deposits described above, it is evident that calc-alkaline suite samples have higher ratios of pyrite/magnetite and muscovite/biotite than those of the alkali suite. This observation, together with the differences in titanium mineralogy, supports the contention that rutile in these deposits derives mainly from the sulfidation of mafic minerals during hydrothermal alteration (Force, 1976). It also suggests that rutile is enriched in the phyllic alteration zone. In contrast, rutile in porphyry copper deposits of the southwestern United States is prominent in propylitic and argillic zones (Creasey, 1966) and less commonly in the potassic zone (Force, 1976).

More assessment is needed to evaluate the feasibility of recovering the titanium minerals. Table 3 shows the titania content of various size fractions of tailing samples from four of the deposits (one from each group) where rutile appears to be the dominating titaniferous species. Whereas in each of these cases, the differences in titania are well within experimental error, the finer grained fractions are consistently higher in titania. Heavy liquid mineral separation performed on the 60 to 100 mesh fraction of most samples failed to significantly concentrate titanium minerals. These observations suggest that efficient recovery of titanium minerals from the tailings requires an optimum grain size of less than 250 mesh. Thus for many tailings regrinding may be required and only deposits with relatively high titania content and the right titanium ore mineralogy warrant further study. In the group of deposits examined, only Equity Silver apparently meets these requirements.

After experimenting with several beneficiation methods on a sample of porphyry copper mill tailings containing 0.75 per cent TiO_2, Llewellyn and Sullivan (1980) concluded that flotation was the most promising technique for rutile beneficiation. Similar experiments with tailings of the Equity Silver deposit appear to be a logical step in assessing the feasibility of rutile recovery from this deposit.

In conclusion, whereas calc-alkaline porphyry deposits generally contain less titania than alkaline suite deposits, they constitute a better potential source of by-product titanium because they contain rutile. Among the 14 deposits investigated in this study, a transitional porphyry system deposit (Cyr, *et al.*, 1984), Equity Silver, shows the highest titania content (about 1 per cent) and a significant amount of rutile. Flotation testing of more finely ground samples is a further necessary step in assessment of the feasibility of recovering rutile from this deposit.

REFERENCES

Cann, R. M. (1979): Geochemistry of Magnetite and the Genesis of Magnetite-apatite Lodes in the Iron Mask Batholith, British Columbia, unpub. M.Sc. thesis, *Univ. of British Columbia*, 196 pp.

Creasey, S. C. (1966): Hydrothermal Alteration, *in* Geology of the Porphyry Copper Deposits, Southwestern North America, S. R. Titley and C. L. Hicks, editors, *Univ. of Arizona Press*, pp. 51-74.

Cyr, J. B., Pease, R. B., and Schroeter, T. G. (1984): Geology and Mineralization at Equity Silver Mine, *Econ. Geol.*, Vol. 79, pp. 947-968.

Deer, W. A., Howie, R. A., and Zussman, J. (1966): An Introduction to the Rock Forming Minerals, *Longman Group Ltd.*, London, 528 pp.

Drummond, A. D. and Godwin, C. I. (1976): Hypogene Mineralization: An Emperical Evaluation of Alteration Zoning, *in* Porphyry Deposits of the Canadian Cordillera, A. Sutherland Brown, editor, *C.I.M.*, Special Vol. 15, pp. 52-63.

Force, E. R. (1976): Titanium Minerals in Deposits of Other Minerals, *U.S.G.S.*, Prof. Paper 959-F, 5 pp.

Force, E. R., Czamanske, G. K., and Moore, W. J. (1979): Rutile from Porphyry Copper Deposits, *Soc. Min. Eng.*, Technical Program, February 1980, Las Vegas, p. 21.

Kerr, P. F. (1959): Optical Mineralogy, *McGraw-Hill Book Co., Inc.*, 442 pp.

Llewellyn, T. O. and Sullivan, G. V. (1980): Recovery of Rutile from Porphyry Copper Tailings, *U.S. Bureau Mines*, Rept. of Investigations 8462, 18 pp.

Ney, C., Anderson, J. M., and Panteleyev, A. (1972): Discovery, Geologic Setting, and Style of Mineralization, Sam Goosly Deposit, British Columbia, *C.I.M.*, Bull., Vol. 65, No. 723, pp. 53-64.

SLOPE ANGLE CORRECTION COMPUTER PROGRAM FOR A ONE-MAN SURVEY

By G. G. Addie

PROBLEM

In surveys which require slope corrections, for example, staking, making of grid, or road traverses, an accurate measurement of the ground slope is required. Normally an assistant's height is sufficient, but in doing a survey alone another method is necessary.

SOLUTION

By sighting onto the ground and knowing the distance from the eye height, the following formula can be used to accurately calculate the slope angle.

DEFINITION

The angle of sight (A/S) is the declination above (+) or below (-) the horizon, measured with a clinometer.

METHOD

The geometric relationship of the line of sight to slope angle is given by the following formula and illustrated on Figure 128.

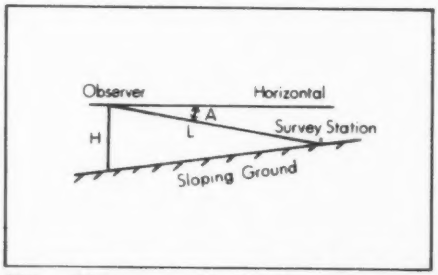


Figure 128. Diagram outlining the survey method.

The ground slope C° = Arctan (B°)
where $B = (L \sin A + H)/(L \cos A)$
L is the length (in this case, metres)
H is the eye height (metres)
A is the angle of sight (A/S) (in degrees)

Note: it is necessary to keep the sign + or - of the A/S in this program.

A computer program for TRS 80 (Model I, Level II) using a negative A/S is as follows:

```
 10 LPRINT  "SLOPE ANGLE CORRECTION"
 20 LPRINT""
 30 LPRINT "       BY GEORGE ADDIE P.ENG"
 40 LPRINT ""
 50 LPRINT "           MARCH 12 1984"
 60 INPUT "LENGTH IS       ";L
 70 INPUT "OBSERVER'S EYE HEIGHT   ";H
 85 LPRINT ""
 90 LPRINT "ANGLE OF SIGHT","TRUE SLOPE"
100 LPRINT ""
110 FOR A=-1 TO -30 STEP-1
120 B=(L*SIN(.01745329*A)+H))/(L*COS(.01745329*A))
125 C=ATN(B)*57.29578
130 LPRINT A,C
140 NEXT A
150 END
```

The results are found in Table 1 for a distance of 5 metres and eye height of 1.518 metres.

TABLE 1
TABLE FOR 5 METRES, EYE HEIGHT OF 1.518 METRES, AND NEGATIVE ANGLE OF SIGHT

ANGLE OF SIGHT	TRUE SLOPE (IN DEGREES)
-1	15.9707
-2	15.0489
-3	14.123
-4	13.1928
-5	12.2582
-6	11.3192
-7	10.3757
-8	9.42754
-9	8.47473
-10	7.51712
-11	6.55466
-12	5.58723
-13	4.61478
-14	3.63719
-15	2.65437
-16	1.66624
-17	.672708
-18	-.326344
-19	-1.33096
-20	-2.34127
-21	-3.35738
-22	-4.37933
-23	-5.40727
-24	-6.44125
-25	-7.48138
-26	-8.52778
-27	-9.58049
-28	-10.6396
-29	-11.7053
-30	-12.7776

To produce a table for positive A/S, line 110 is changed to: For A = 1 to 30 Step 1.

Tables can be made for any length (L) by changing the input on line 60, any eye height by changing line 70, and any number of angles of sight by changing line 110.

CONCLUSION

The computer program presented calculates slope angles measured from eye level, based on the angle of sight and distance to the ground. This can then be used to calculate the necessary slope correction for staking or making grids.

RESOURCE DATA AND ANALYSIS

MINERAL RESOURCE ASSESSMENTS - ACTIVITIES OF THE LAND USE OFFICE

By A. Ratel

INTRODUCTION

The Land Use Office is responsible for developing reports which document the position of the Ministry of Energy, Mines and Petroleum Resources for land use planning projects throughout the Province. Such projects include: park and recreation area proposals, ecological reserve proposals, mineral reserve requests, official settlement plans, and Crown land allocation plans. The various property files, publications, and staff resources of the Geological Branch provide a vital part of the information base for the Ministry's recommendations on land use projects.

SOUTH MORESBY

Work was completed on the South Moresby Resource Plan in 1984 and the report publicly released after five years of study. The Ministry of Energy, Mines and Petroleum Resources presented a minority opinion in the report because none of the four alternatives developed by the other planning team members met mineral policy objectives. Principal among those objectives is that evaluation and determination of mineral resource potential should precede any alienation of the land base. In the four options endorsed by the other team members, preservation ranges from 33 per cent (Option 1) to 95 per cent (Option 4) of the total land base of 145 000 hectares. The report has been presented to the Environment and Land Use Committee of Cabinet. Several Cabinet Ministers and their senior staff toured the area at the end of June. No decision has been reached yet.

SLOCAN VALLEY

The Slocan Valley Planning Program, which began in 1981, culminated with release of the final draft of the Slocan Valley Development Guidelines in September, 1984. This program was the first joint venture between the Province and a regional district in a planning exercise. Extensive

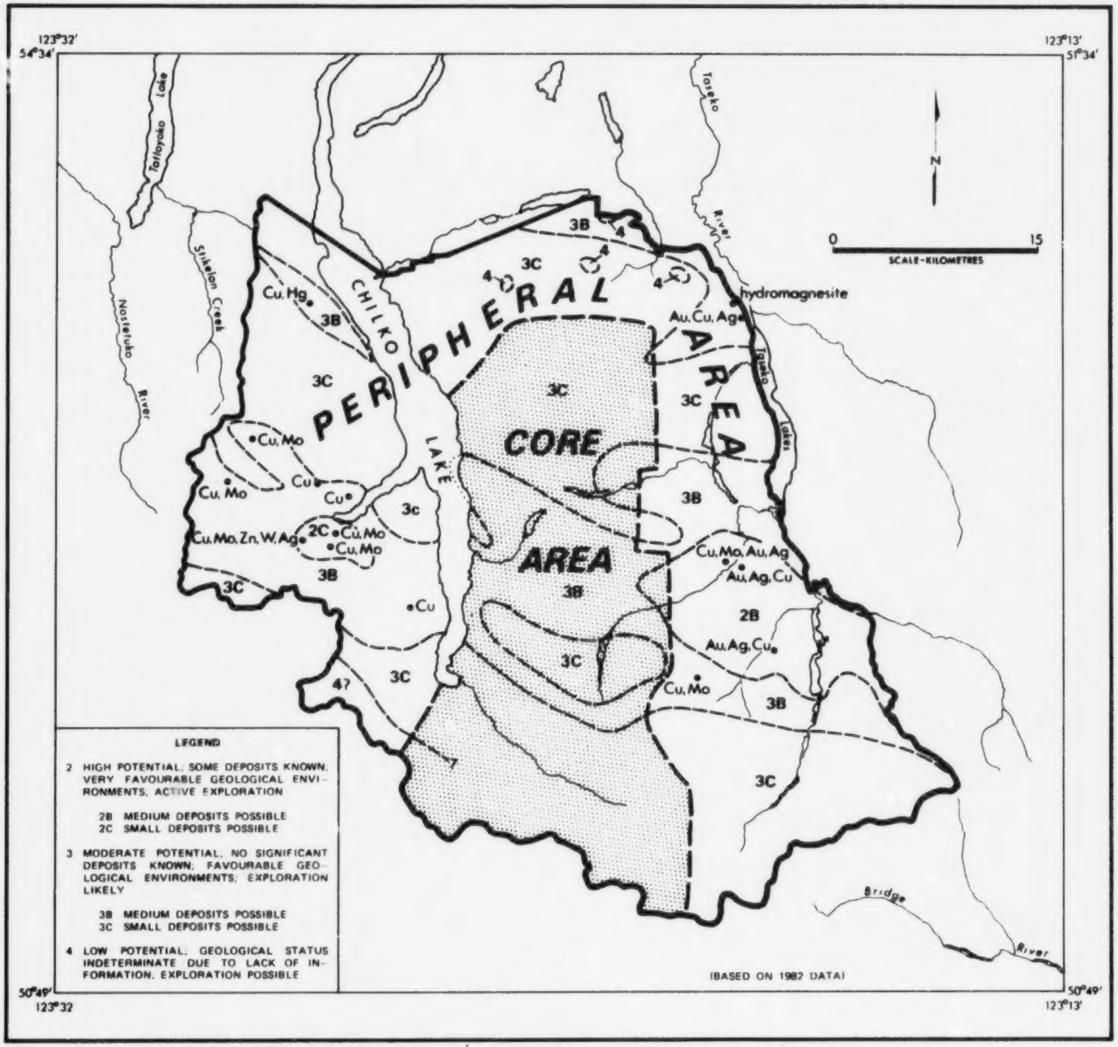

123°32'
54°34'
123°13'
51°34'
50°49'
123°32
50°49'
123°13'
N
0
15
SCALE-KILOMETRES
Taseko River
Taseko Lakes
Tatlayoko Lake
Stikelon Creek
Nostetuko River
Bridge River
CHILKO LAKE
PERIPHERAL AREA
CORE AREA
hydromagnesite
Au, Cu, Ag
Cu, Hg
Cu, Mo
Cu
Cu, Mo, Zn, W, Ag
Cu, Mo, Au, Ag
Au, Ag, Cu
Cu, Mo
3B
3C
2B
2C
4
4?
LEGEND
2 HIGH POTENTIAL: SOME DEPOSITS KNOWN; VERY FAVOURABLE GEOLOGICAL ENVIRONMENTS; ACTIVE EXPLORATION
2B MEDIUM DEPOSITS POSSIBLE
2C SMALL DEPOSITS POSSIBLE
3 MODERATE POTENTIAL, NO SIGNIFICANT DEPOSITS KNOWN; FAVOURABLE GEOLOGICAL ENVIRONMENTS; EXPLORATION LIKELY
3B MEDIUM DEPOSITS POSSIBLE
3C SMALL DEPOSITS POSSIBLE
4 LOW POTENTIAL: GEOLOGICAL STATUS INDETERMINATE DUE TO LACK OF INFORMATION, EXPLORATION POSSIBLE
(BASED ON 1982 DATA)

Figure 129. Mineral Potential of Chilko Lake.

involvement of both headquarters and district staff was required to develop the mineral evaluations, and provide the technical information and policy direction necessary to meet the terms of reference for the program. This year another series of public meetings were held including one to provide information on forest landscape management and exploration/mining requirements. Considerable effort was devoted to revising earlier drafts of the guidelines to ensure that policies would provide for continued mineral exploration. In themselves, the guidelines do not allocate land or regulate land use, but they have been the focus of much public debate. The Regional District of Central Kootenay has presented the document to the Environment and Land Use Committee of Cabinet.

CHILKO LAKE PARK PROPOSAL

Discussions with the Ministry of Lands, Parks and Housing regarding the Chilko Lake Park Proposal currently are stalemated. In the spring of 1984, the Parks Branch proposed designating both the core and peripheral areas of this proposal as a recreation area (Fig. 129). The Ministry of Energy, Mines and Petroleum Resources countered by proposing to establish a recreation area, zoned to permit exploration, only over the core area. This proposal maintains the peripheral area as unalienated Crown land or recommends its designation as provincial forest to avoid subjecting exploration programs to Parks Branch regulations. The Ministry awaits a response from the Parks Branch to this counteroffer.

MINING AND PARKS

For many years the Ministry of Energy, Mines and Petroleum Resources has been negotiating with the Ministry of Lands, Parks and Housing to develop means to allow exploration of mineral properties within park boundaries. This year, the Parks Branch began a reclassification process for their park system. Currently, parks are classified four ways: Class A, Class B, Class C, and Recreation Area. Under the new system there are just two classifications - Class A parks and Recreation Areas. Class A status will continue to protect the natural environment and recreation values of the land; resource and land use will be restricted to the preservation and maintenance of recreational values. Recreation Area status will continue to protect recreation values; non-recreational use of land and resources may be permitted albeit in a controlled manner.

For the most part, local authorities will manage the current Class C parks. Studies made of Class B parks will determine which areas within them should be included in the Class A or Recreation Area designations and which should be excluded from the park system altogether. Three Class B parks are of particular interest to explorationists: Tweedsmuir, Kokanee Glacier, and Strathcona. The park reclassification initiative may provide a mechanism to free known mineral properties from the park system. No Class B or C parks have been designated in recent years; this initiative is, therefore, a logical extension of recent designation policy.

AREAS ALIENATED OR RESTRICTED FROM MINING IN BRITISH COLUMBIA 1984

Alienation and restriction of lands from mining is the subject of Preliminary Map 55 which was released in early 1984. The map, at scale 1:2 000 000, shows the location of parks, recreation areas, ecological reserves, Indian Reserves, flooding reserves, and the Agricultural Land Reserve. Gross areas for these alienations and restrictions are listed as part of the legend. Twelve planning projects, which could result in further alienations of lands, also are depicted.

FIELDWORK IN SUPPORT OF MINERAL POTENTIAL EVALUATIONS

During the summer of 1984 several field studies were undertaken in areas proposed for alienation from the mineral land base. District Geologist Andrew Legun further (Legun, 1984) examined the Wokkpash Valley Park Proposal; Senior Geologist Ron Smyth studied the Brooks Peninsula Ecological Reserve Proposal; and District Geologist George Addie evaluated the Syringa Creek and Deer Park Ecological Reserve Proposals. The Legun and Smyth studies are described elsewhere in this volume.

GENERAL INFORMATION

For information concerning specific land use conflicts or general land use policy, please contact: Ann Ratel, Land Use Coordinator, Geological Branch, Ministry of Energy, Mines and Petroleum Resources, Parliament Buildings, Victoria, British Columbia, V8V 1X4.

REFERENCES

Legun, A. (1984): Geologic Reconnaissance of the Wokkpash Park Proposal Area (94K), *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1983, Paper 1984-1, pp. 146-148.

Ratel, A. and Fontaine, J. (1984): Areas Alienated or Restricted from Mining in British Columbia, *B.C. Ministry of Energy, Mines & Pet. Res.*, Preliminary Map 55.

ASSESSMENT REPORTS

By A. Wilcox, M. Gardiner, and C. Sturko

MINERAL ASSESSMENT REPORTS

Title to a mineral claim is maintained either by paying cash or recording exploration and development work which adds information to the mineral data base. Value credited for assessment work is determined from the content and cost of original work done on the claims as described in an assessment report.

Utilizing assessment reports to access exploration credit was started in 1947 in British Columbia. Since that time more than 12 500 assessment reports have been accepted by the Resource Data and Analysis Section. Most reports are held confidential for one year from the date of filing, but if requested confidential periods to three or five years for regional surveys and drilling/assay reports are given.

Assessment report locations are plotted on paper and mylar index maps of 1:125 000 and 1:250 000 scale. The mylar maps are filmed in January and June and paper prints are available for purchase from the Victoria and Vancouver offices. Assessment reports from 00001-07899 are on aperture cards and are available for viewing and copying in Victoria and Vancouver. Assessment Reports 07900-09999 are on microfiche and are available for viewing at all District Geologists' offices in Vancouver and in Victoria; the microfiche can be reproduced on paper in Victoria. All original assessment reports that have passed the confidentiality period are available for reading and reproduction in Victoria; District Geologists' offices also have copies of all original assessment reports for their respective areas. The Publications Distribution office in Victoria stocks the 'Assessment Report Index,' a computer printout list of assessment reports sorted by NTS map-area and report number. A sequential numerical index and an alphabetical claim index are also available from Resource Data and Analysis Section in Victoria.

As availability of staff and funds allow, old assessment reports on microfilm aperture cards are being converted to microfiche; eventually the entire file will be available on microfiche.

PORTABLE ASSESSMENT CREDITS (PAC)

The PAC program was initiated in 1978 to encourage companies to file exploration reports where expenditures were in excess of work requirements to keep claims in good standing, and from regional surveys where claim tenure was not involved. The expenditures credited to a PAC account may be used in the future in three ways:

(1) for up to 30 per cent of the value of required assessment work on a claim,
(2) to have recording fees refunded, and
(3) to extend claim title for up to 5 years if at least 10 years of work requirements have been previously recorded.

Please refer to the Mineral Act Regulations for details.

In six years of operation (1978 to 1983) approximately 500 companies and individuals have participated in the PAC program submitting $60 million worth of extra exploration results to the government data base, while about $17 million has been debited from the accounts.

COAL ASSESSMENT REPORTS

The Coal Act requires that any exploration work done for credit on coal licences be described in an assessment report; licences may otherwise be kept in good standing by making cash payments. Since the moratorium on issuance of coal licences was lifted in 1978, a dramatic increase in coal exploration has occurred. As a result, Coal Act Regulations were revised in 1979 to give a detailed outline of the format and type of information required in assessment reports. A coal data base, COALFILE, has been created from information in these reports (*see* article by Kenyon, this volume).

The library of assessment reports dates back to the turn of the century, but the bulk of the approximately six hundred reports were submitted within the last six years. The reports are held confidential for three years from the date of submission, and specified analysis data is permanently confidential. Reports on forfeited licences are not confidential.

Assessment reports contain information on the type of work done on a property. This includes mapping, drilling, underground work, logging and sampling, reclamation, and various types of surveys. Histories of the properties and reserve and resource data may also appear. Both the Geological and Inspection Branches must recommend acceptance of the reported costs of various types of work before the Coal Administrator will accept the report.

COALFILE

By Candace E. Kenyon

INTRODUCTION

COALFILE is a computer-based data storage and retrieval system for coal exploration information. The system was implemented to provide a quick, efficient, and organized method for handling information contained in coal company assessment reports. COALFILE's main objectives are to aid in promoting coal exploration in the Province and to act as a resource management tool both at a provincial and federal level. It provides a resource base for the scientific community and acts as a safeguard to assure that a backup of exploration data exists.

HISTORY

Coal exploration greatly increased in 1978 when the moratorium on the issuance of coal licences was lifted. Due to increasing amounts of data, a decision was made in 1978 to computerize information from assessment reports and the British Columbia Ministry of Energy, Mines and Petroleum Resources entered into an agreement regarding data collection with the Institute of Sedimentary and Petroleum Geology in Calgary. British Columbia was to focus on computerizing coal quality data, while the federal government would collect geological data (*see* A. Matheson, this volume). Summus Resources, a consulting company from Alberta, initiated the COALFILE project and maintained it for three years. It then became an in-house project with a resident data base manager and support staff at the British Columbia Systems Corporation (BCSC).

COMPUTER TECHNOLOGY

Since the inception of COALFILE the data base has undergone three major system conversions. It presently resides on the mainframe at BCSC on the IBM 3081 Model K with an MVS operating system. Access to the mainframe is via an IBM 3270 remote terminal and small amounts of hard copy are done on a local IBM 3287 printer (Fig. 130); batch jobs are output on BCSC high speed printers.

The Master file is sequential; it consists of seven varying length record types with a common index to link them. Records are grouped and sorted according to year and index numbers. Files are on disc storage and the IBM 'Wylbur' operating system is used to run batch PLI programs to maintain COALFILE. The Wylbur command files or 'execs' provide access to basic utilities, such as moving files from tape to disc, file creation, backups, restoration, sorts, merges, and file deletions. They also

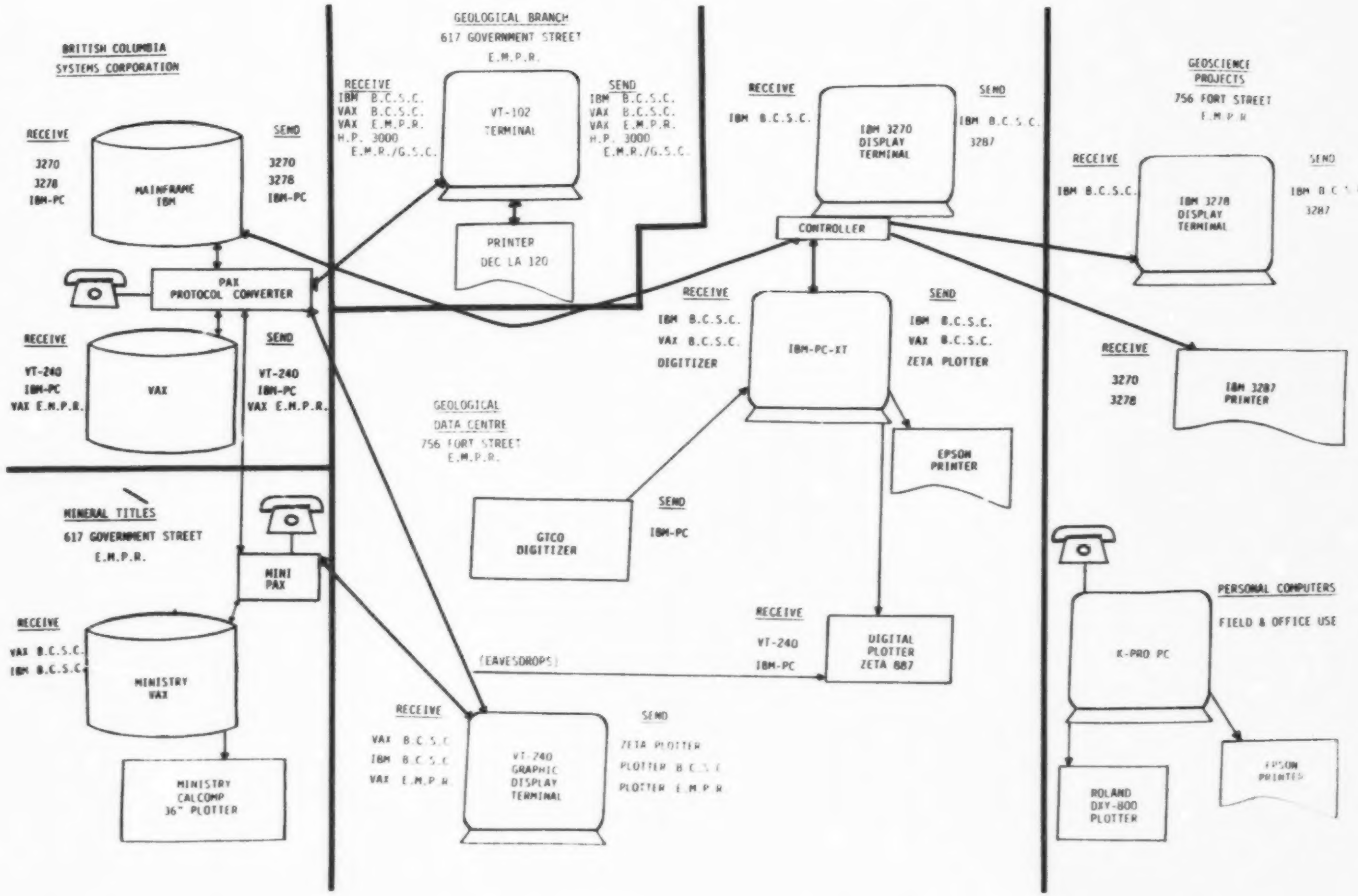

BRITISH COLUMBIA
SYSTEMS CORPORATION
RECEIVE
3270
3278
IBM-PC
MAINFRAME
IBM
SEND
3270
3278
IBM-PC
PAX
PROTOCOL CONVERTER
RECEIVE
VT-240
IBM-PC
VAX E.M.P.R.
VAX
SEND
VT-240
IBM-PC
VAX E.M.P.R.
MINERAL TITLES
617 GOVERNMENT STREET
E.M.P.R.
MINI
PAX
RECEIVE
VAX B.C.S.C.
IBM B.C.S.C.
MINISTRY
VAX
MINISTRY
CALCOMP
36" PLOTTER
GEOLOGICAL BRANCH
617 GOVERNMENT STREET
E.M.P.R.
RECEIVE
IBM B.C.S.C.
VAX B.C.S.C.
VAX E.M.P.R.
H.P. 3000
E.M.R./G.S.C.
VT-102
TERMINAL
SEND
IBM B.C.S.C.
VAX B.C.S.C.
VAX E.M.P.R.
H.P. 3000
E.M.R./G.S.C.
PRINTER
DEC LA 120
GEOLOGICAL
DATA CENTRE
756 FORT STREET
E.M.P.R.
GTCO
DIGITIZER
SEND
IBM-PC
(EAVESDROPS)
RECEIVE
VAX B.C.S.C.
IBM B.C.S.C.
VAX E.M.P.R.
VT-240
GRAPHIC
DISPLAY
TERMINAL
SEND
ZETA PLOTTER
PLOTTER B.C.S.C.
PLOTTER E.M.P.R.
RECEIVE
IBM B.C.S.C.
IBM 3270
DISPLAY
TERMINAL
SEND
IBM B.C.S.C.
3287
CONTROLLER
RECEIVE
IBM B.C.S.C.
VAX B.C.S.C.
DIGITIZER
IBM-PC-XT
SEND
IBM B.C.S.C.
VAX B.C.S.C.
ZETA PLOTTER
EPSON
PRINTER
RECEIVE
VT-240
IBM-PC
DIGITAL
PLOTTER
ZETA 887
GEOSCIENCE
PROJECTS
756 FORT STREET
E.M.P.R.
RECEIVE
IBM B.C.S.C.
IBM 3278
DISPLAY
TERMINAL
SEND
IBM B.C.S.C.
3287
RECEIVE
3270
3278
IBM 3287
PRINTER
PERSONAL COMPUTERS
FIELD & OFFICE USE
K-PRO PC
ROLAND
DXY-800
PLOTTER
EPSON
PRINTER

Figure 130. Geological Branch computing network.

provide a means of loading data, doing corrections, retrieving specific data, producing files for plots and statistical uses, printing forms, defining program function (PF) keys, and providing an aid to deal with problems encountered through a 'HELP' facility.

The software packages, SPSS, APL, SASS, and Culprit, interpret and display the data in report of graphical format, such as pie charts, bar graphs, and histograms. A plotting program designed for the Ministry in Virtual System (VS) Fortran which operates in Time Sharing Option (TSO) foreground enables us to produce x, y coordinate plots of exploration data at any scale. Tectronics software allows preview capabilities on the VT 240 (Fig. 130). Hard copy is presently done at BCSC.

The system is RACF (Resource Access Control Facility) protected with multiple security levels.

TYPE OF DATA

Information is extracted from assessment reports submitted each year and coded on data entry forms. The data is keypunched to tape, verified, and appended to the Master file. Data remains confidential for a three-year period from the date a company submits the report. Each report has as many as seven records associated with it, dependent upon the type of work done that year.

(1) Explore Record - Contains general information such as property ownership, location, type of work done, and licence area. Each coal property in the Province has a unique identifier in the file.

(2) Comment Record - This is reserved for text concerning the report (for example, whether report is complete).

(3) Map Record - Indicates the type of maps, including scale and area, that were submitted with the assessment report.

(4) Trench Record - Provides location, type of exposure, sample types, and other features but does not include analytical data for trench samples.

(5) Adit Analysis Record - Contains location information as well as depth, orientation, and comprehensive coal quality data determined from underground bulk samples.

(6) Borehole Record - Provides location information, number of coal intersections, type and depth of hole, number of samples taken, contractor, types of geophysical logs run, and other data.

(7) Borehole Analysis Record - This record contains detailed coal quality data for each sampled interval in a borehole.

Once the 1984 data has been appended, data from 602 assessment reports will reside in the Master file.

A computer printout is available listing all non-confidential assessment reports on file with the Ministry. Specific retrievals can be done upon request and detailed descriptions of the data fields for each record can be obtained.

SUMMARY OF RECORDS STORED IN COALFILE

Record Type	Total Records as of Oct. 1983	1984 Work to be Appended	Total No. of Records
Explore	582	20	602
Comments	496	65	561
Maps	485	25	510
Trench	2 582	217	2 799
Adit Analysis	578	33	611
Borehole	6 019	129	6 148
Borehole Analysis	13 601	845	14 446

PLANS FOR COALFILE

An IBM-PC XT resides in the Geological Data Centre. It uses the MSDOS operating system and has a 640K memory capacity. An IRMA board (which allows the PC to act as a 3270 terminal) in this machine enables downloading from the mainframe at BCSC (Fig. 1) to the personal computer. One of the software packages purchased for the PC is FOCUS, a fourth generation language. The records in COALFILE are presently being defined to FOCUS, which contains user freindly, menu-driven programs to produce reports, statistical results, and graphs. Tests will be run to see if it is feasible to produce hard copy from the IBM PC on the Epson printer and the Zeta 887 digital plotter (eight pens).

We plan to attempt to develop data entry screens on the PC which can be uploaded to the mainframe, where the Master file will continue to reside because of the volumes of data. Data coding and updates will then be made on the personal computer which will eliminate the need to code on data entry forms and the keypunching step; both introduce errors. Software also is being installed which will enable plots to be printed on the Ministry Calcomp plotter to lessen our dependence on BCSC.

To obtain further information about COALFILE please contact Candace Kenyon at (604) 387-1301.

CANADA/BRITISH COLUMBIA COAL DATA PROJECT

By B. J. Thompson and A. Matheson

INTRODUCTION

In March, 1978 the Geological Branch of the British Columbia Ministry of Energy, Mines and Petroleum Resources and the Institute of Sedimentary and Petroleum Geology (ISPG) of the Geological Survey of Canada (GSC) initiated a project to compile non-geological, location, and analytical data into a computer-processible format. Summus Resource Evaluations Ltd. was contracted for three years to construct computer files, containing data up to 1977, which resulted in COALFILE (refer to article by C. Kenyon, this volume). Upon completion of this contract the Geological Branch assumed responsibility for updating these files.

PRESENT AGREEMENT

A new three-year agreement began in March, 1983 to collect geological data in addition to non-geological data for computer based reserve and resource evaluations. Each agency funds its own share of the project and exchanges the data collected.

OBJECTIVES

Both provincial and federal governments require sound estimates of the coal resources of British Columbia, therefore reliable and uniform criteria for each coal basin will be established. To aid in the resource estimates, geological models of coal deposits in mountainous terranes are being developed. In addition, industry is provided with access to continually updated geological data to facilitate exploration and development.

DATA COLLECTION

Data is collected by both agencies from the annual assessment reports submitted by companies in accordance with the Coal Act Regulations.

The Geological Branch's contribution is to update COALFILE and build computer files of the digitized outcrop data. A consultant, Jill Thompson (Geocal Consulting), under contract since December, 1980, has been calculating reserves and resources manually for the publication 'Coal in British Columbia,' as well as for this project.

The data is digitized on a 91 by 122 centimetre graphic tablet digitizer, a Digi-pad 5 Model by GTCO Corporation, using a 16-button cursor with a crosswire reticle and 0.002-centimetre resolution. The digitizer is connected to an IBM PC XT micro-computer, Epson printer, and Zeta digital plotter in the Geological Data Centre (refer to article by C. Kenyon, this volume).

The GSC is responsible for completing a computer model of the Sukunka coal property. In addition they will interpret approximately 40 000 metres of lithological and geophysical borehole logs annually for future modelling. Cal Data Ltd. has been contracted by the GSC since February, 1984 to analyse the Quintette property boreholes.

The GSC has installed a data entry terminal in the Geological Branch (Victoria) connected by a dedicated telephone line to the Hewlett-Packard 3000 mini-computer facility at the ISPG in Calgary.

ANALYSIS AND RESOURCE ESTIMATION

The computer based files are used to analyse, manipulate, and display the large volumes of geoscience, coal quality, and resource data generated by industry. Branch geological staff utilize the Geological Analysis Package by Cal Data Ltd., Graphics Analysis Package #1 by GTCO Corporation, and the Coal Outcrop Digitizing in-house program in the surficial data collection and reserve and resource studies.

The major benefit of the project to the Geological Branch will be the capability to rapidly update reserve and resource estimates resulting from new geological data or different economic or technological criteria. The Geological Branch provides reserve and resource estimates to the British Columbia government for resource development and land use planning decisions.

The GSC will incorporate the British Columbia resource estimates into the calculation of national coal resources.

MINFILE - PAST, PRESENT, AND FUTURE

By A. Wilcox and C. Ritchie

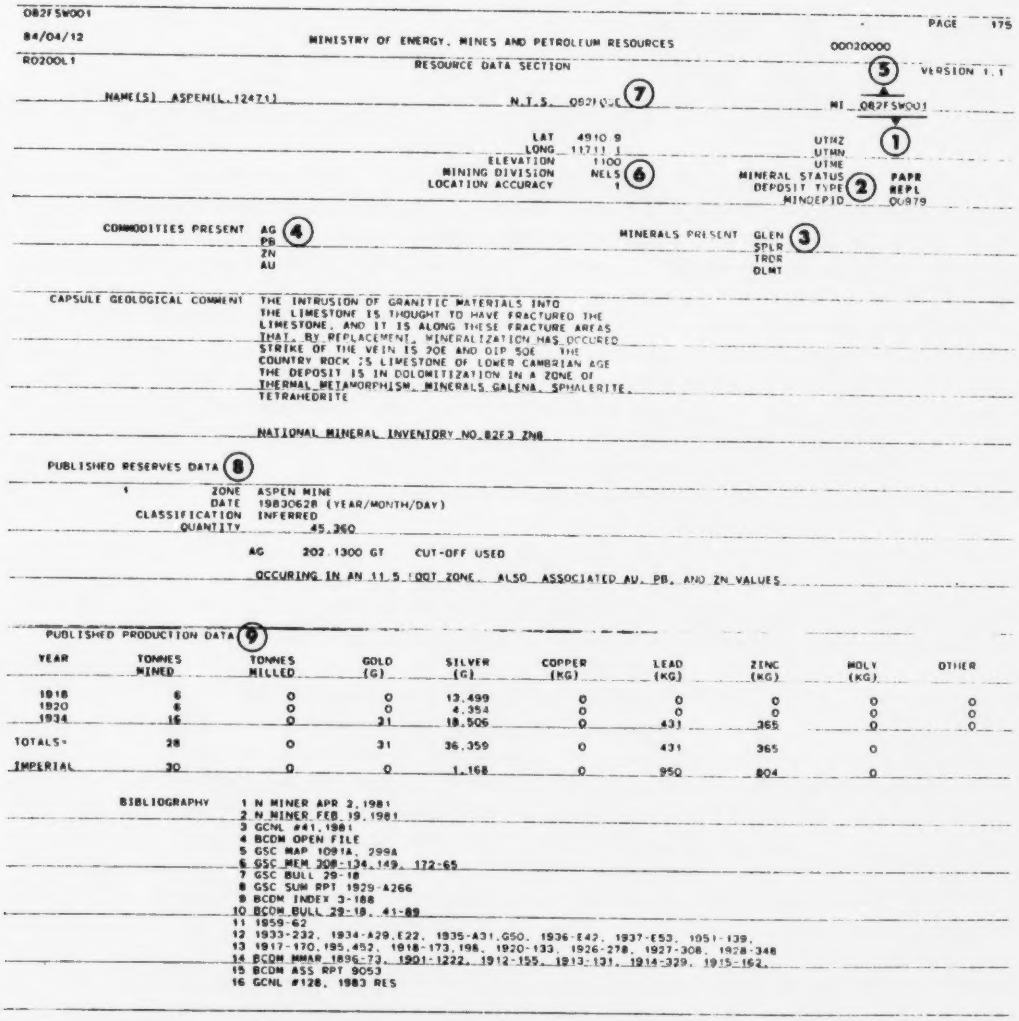
Numerous changes have taken place in the methods of collection, storage, and distribution of mineral inventory data by the Province of British Columbia since the inception of the mineral inventory file system 17 years ago.

PAST

A mineral inventory system consisting of a series of mineral deposit maps and a corresponding card file was started by the Geological Branch in 1967. This was a manual card file consisting of one card per deposit, and information recorded included: (1) identification; (2) location; (3) history of discovery; (4) status of mining or exploration; (5) work history; (6) references; (7) geological summary; and (8) detailed geology using 15 descriptive parameters. This system was difficult to use and complete so in 1969 plans were made to redesign the forms used for data capture to make the file compatible for computer storage using I.D. location, status, references, and geology. By working with the currently active properties, the Ministry planned to obtain as complete a coverage of the Province in as short a time as possible.

MINDEP was a research project initiated by the Department of Geological Sciences at the University of British Columbia, and initially financed primarily by research grants from the Ministry of Energy, Mines and Petroleum Resources and the federal Department of Energy, Mines and Resources to Drs. H. R. Wynne-Edwards and A. J. Sinclair. The objectives of the project were to develop a computer-processible mineral deposits data file, and to design methods for data retrieval and manipulation. The program was under the direction of Dr. J. H. Montgomery (Wynne-Edwards and Sinclair, 1976). The mineral inventory cards maintained by the Ministry of Energy, Mines and Petroleum Resources became the main source of basic data for the MINDEP project; it also incorporated data obtained from the MacDonald File (Montgomery, *et al.*, 1975; Sinclair, *et al.*, 1976), a private industry mineral deposits file.

MINDEP was transferred from the University of British Columbia to the computer facilities of the British Columbia Systems Corporation (BCSC) in 1976. With this transfer the file was renamed MINFILE and the task of maintaining data entry, and updating became the responsibility of the Resource Data and Analysis Section in Victoria. Initially MINFILE resided on a Honeywell 6066 computer and control programs were written in Cobol. A conversion took place in 1981 in which BCSC changed operating systems from Honeywell to IBM; the control progams were also converted to PL1.



```
082FSW001                                                                                    PAGE    175
84/04/12                  MINISTRY OF ENERGY, MINES AND PETROLEUM RESOURCES          00020000
R0200L1                                RESOURCE DATA SECTION                             ⑤   VERSION 1.1

          NAME(S)  ASPEN(L.12471)                       N.T.S.  082F03E ⑦              MI  082FSW001
                                                                                            ①
                                              LAT    4910.9                        UTMZ
                                             LONG   11711.1                        UTMN
                                        ELEVATION    1100                          UTME
                                  MINING DIVISION    NELS ⑥             MINERAL STATUS     PAPR
                                LOCATION ACCURACY       1                  DEPOSIT TYPE ②  REPL
                                                                               MINDEPID    00979

          COMMODITIES PRESENT  AG ④                          MINERALS PRESENT  GLEN ③
                               PB                                              SPLR
                               ZN                                              TRDR
                               AU                                              DLMT

     CAPSULE GEOLOGICAL COMMENT  THE INTRUSION OF GRANITIC MATERIALS INTO
                                 THE LIMESTONE IS THOUGHT TO HAVE FRACTURED THE
                                 LIMESTONE, AND IT IS ALONG THESE FRACTURE AREAS
                                 THAT, BY REPLACEMENT, MINERALIZATION HAS OCCURED
                                 STRIKE OF THE VEIN IS 20E AND DIP 50E   THE
                                 COUNTRY ROCK IS LIMESTONE OF LOWER CAMBRIAN AGE
                                 THE DEPOSIT IS IN DOLOMITIZATION IN A ZONE OF
                                 THERMAL METAMORPHISM. MINERALS GALENA, SPHALERITE,
                                 TETRAHEDRITE

                                 NATIONAL MINERAL INVENTORY NO.82F3 ZN8

     PUBLISHED RESERVES DATA ⑧
                  1          ZONE  ASPEN MINE
                             DATE  19830628 (YEAR/MONTH/DAY)
                   CLASSIFICATION  INFERRED
                         QUANTITY        45,360

                                 AG      202.1300 GT      CUT-OFF USED

                                 OCCURING IN AN 11.5 FOOT ZONE.  ALSO  ASSOCIATED AU, PB, AND ZN VALUES


     PUBLISHED PRODUCTION DATA ⑨
     YEAR        TONNES       TONNES       GOLD      SILVER      COPPER      LEAD       ZINC       MOLY       OTHER
                 MINED        MILLED       (G)       (G)         (KG)        (KG)       (KG)       (KG)

     1918           6            0           0       13,499         0           0          0          0          0
     1920           6            0           0        4,354         0           0          0          0          0
     1934          16            0          31       18,506         0         431        365          0          0

    TOTALS=        28            0          31       36,359         0         431        365          0

    IMPERIAL       30            0           0        1,168         0         950        804          0

               BIBLIOGRAPHY    1 N MINER APR 2,1981
                               2 N MINER FEB 19,1981
                               3 GCNL #41,1981
                               4 BCDM OPEN FILE
                               5 GSC MAP 1091A, 299A
                               6 GSC MEM 308-134,149, 172-65
                               7 GSC BULL 29-18
                               8 GSC SUM RPT 1929-A266
                               9 BCDM INDEX 3-188
                              10 BCDM BULL 29-18, 41-89
                              11 1959-62
                              12 1933-232, 1934-A29,E22, 1935-A31,G50, 1936-E42, 1937-E53, 1951-139,
                              13 1917-170,195,452, 1918-173,198, 1920-133, 1926-278, 1927-308, 1928-348
                              14 BCDM MMAR 1896-73, 1901-1222, 1912-155, 1913-131, 1914-329, 1915-162,
                              15 BCDM ASS RPT 9053
                              16 GCNL #128, 1983 RES
```

Figure 131. Typical MINFILE printout.

PRESENT

At the present time there are approximately 8 900 mineral occurrences listed in MINFILE; a mineral occurrence is defined as a concentration of any ore or economic mineral in bedrock, but excluding geochemical or geophysical anomalies or mineralized float. Incomplete placer and coal deposit information are also captured. The system resides on an IBM 3081 mainframe computer at the BCSC offices in Victoria. Inquiry into the system is by batch mode. Searching may be carried on any of the following nine categories (*see* Fig. 131):

(1) B.C. Map number
(2) Deposit type
(3) Minerals present
(4) Commodities present
(5) NTS quadrangle
(6) Mining Division
(7) NTS
(8) Reserves data
(9) Production data

MINFILE is available to the public in three formats: microfiche, computer tape, and paper. The first two contain the complete file; the paper output may contain the whole file or may be part of a customized search on any of the nine categories above. Two cross-reference indexes are also available: alphabetical by property name, and by commodity. Mineral inventory maps at a scale of 1:125 000 or 1:250 000 are also available; these show location, property name, mineral inventory number, and commodities present.

Data is passed freely between Victoria and Ottawa, where MINFILE data is used to contribute to the National Mineral Inventory file.

FUTURE

MINFILE is currently undergoing a redesign to serve five main functions: (1) in conjunction with the Ministry's five-year plan to provide a better enquiry base for mineral inventory data for Ministry and industry use, (2) to eliminate long-term problems caused by converting from Honeywell to IBM mainframe, (3) to be able to down-load parts of data base onto personal computers for use by individual geologists in government and industry, (4) to provide graphic output capabilities, and (5) to provide a lead-in to 'expert' systems.

The working/steering committee formed decided at an early stage that the only practical choice of hardware was the VAX mini-computer already installed in the Mineral Titles Branch of the Ministry. The committee decided to develop a table-driven, relational data base. Geological Survey of Canada Paper 78-26 'Computer-based files on mineral deposits:

Guidelines and recommended standards for data content' (Longe, *et al.*, 1978) was used to define certain areas and tables, and as a broad guide to the data base structure. The main tables to be included are: (a) economic minerals; (b) deposit type; (c) commodity; (d) age of deposit; and (e) name of formation (host rock). In addition to the tables, narrative (textual) descriptions will be associated with any area of the data base.

Implementation Schedule

1984/85:

(1) Consultation on data base design with:
    (a) Victoria staff
    (b) District geologists
    (c) Industry groups in Vancouver
    (d) Energy, Mines and Resources/Geological Survey of Canada
(2) Revisions to data base design
(3) Final choice of software and programming
(4) Pilot test conversion of system

1985/86:

(5) Programming to capture new data
(6) Complete conversion to new system
(7) Testing
(8) Routine production

Further information on the system or order inquiries may be made by telephone or directed to either of the authors at the following address:

Geological Branch
Mineral Resources Division
Ministry of Energy, Mines and Petroleum Resources
Parliament Buildings
Victoria, British Columbia
V8V 1X4
(604) 387-5975

REFERENCES

James, G. L. (1979): British Columbia Mineral Exploration Information: Resources Branch Has a Wealth of Data, *Western Miner*, Vol. 52, No. 7, pp. 15-22.

Longe, R. V., Burk, C. F., Dugas, J., Ewing, K. A., Ferguson, S. A., Gunn, K. L., Jackson, E. V., Kelly, A. M., Oliver, A. D., Sutterlin, P. G., and Williams, G. D. (1978): Computer-based Files on Mineral Deposits: Guidelines and Recommended Standards for Data Content, *Geol. Surv., Canada*, Paper 78-26.

Montgomery, J. H., Sinclair, A. J., Wynne-Edwards, H. R., Fox, A.C.L., and Giroux, G. H. (1975): Data Capture in the Construction of MINDEP's Computer-based Mineral Deposits File, *Cdn. Jour. Earth Sci.*, Vol. 12, No. 4, pp. 698-703.

Sinclair, A. J., Wynne-Edwards, H. R., and Montgomery, J. H. (1976): Some Geological Applications of the MINDEP Computer-based Filing System for Mineral Deposit Data, *C.I.M.*, Bull., Vol. 69, No. 772, pp. 119-125.

Wynne-Edwards, H. R. and Sinclair, A. J. (1976): MINDEP Computer-processible Files of Mineral Deposit Information, *Western Miner*, Vol. 49, No. 2, pp. 10-18.

MULTIPLE REGRESSION, A USEFUL QUANTITATIVE APPROACH IN EVALUATING PRODUCTION DATA FROM VEIN-TYPE MINING CAMPS, SOUTHERN BRITISH COLUMBIA

By L. B. Goldsmith and A. J. Sinclair
Department of Geological Sciences, University of British Columbia

INTRODUCTION

Relatively little has been published on the development of quantitative mineral resource models of direct use in mineral exploration and evaluation. Nevertheless, an interesting array of literature pertaining to British Columbia has appeared since the late 1960's. An early study by Kelly and Sheriff (1969) was concerned with estimating the economic mineral potential of 20 by 20-square-mile cells over the entire Province in terms of gross dollar value of all contained mineral deposits. A comparable methodology was applied on a different scale and with more detailed geological information (4 by 4-square-mile cells) in the Terrace area by Sinclair and Woodsworth (1970). Most recently this 'cell' approach was applied by Godwin and Sinclair (1979) in an evaluation of a single porphyry-type deposit, the Casino copper-molybdenum deposit in Yukon Territory, based on a 400 by 400-square-foot cell size. All these studies related some measure of cell value (the dependent variable) to a variety of geological and other attributes of the cells (independent variables) by a multiple regression relationship.

Multiple regression has also been applied to the development of quantitative models for the relative worth of individual deposits within a mining camp (Orr, 1971; Orr and Sinclair, 1971; Sinclair, 1979; Sinclair, 1982). Models derived from these latter studies have a relative value measure for deposits (such as log of production tonnage) as the dependent variable and logarithm of average grade figures for several metals, such as silver, lead, zinc, and gold, as independent variables. The most extensive test to date by Sinclair (1982) for the Slocan silver-lead-zinc-gold camp suggests several important applications of the method:

(1) Newly located deposits can be sampled and the average grades used to estimate potential size (value), thus providing a quantified target for further exploration.

(2) A statistical model will isolate those deposits that do not fit the general model. In particular, deposits with low recorded production that have grade characteristics of large deposits warrant further detailed examination.

(3) In some mining camps it may be useful to contour 'values' calculated according to a multiple regression model as one means of examining systematic variations of relative worth in order to delimit areas for detailed exploration.

PROCEDURE

A necessary precursor to the multiple regression approach to exploration model development is the availability of appropriate production information. For this purpose, computer files, developed or improved, were used as follows: Slocan, Slocan City, and Ainsworth camps - Orr (1971) and Orr and Sinclair (1971); Zeballos camp - Sinclair and Hansen (1983); Trout Lake camp - Read (1976) and Goldsmith (1984).

The multiple regression method involves selection of a value measure for each deposit for which production data are available. Log_{10} production tonnage was selected as a satisfactory relative value measure based on results by Sinclair (1979). Similarly, dependent variables were mostly logarithms of average deposit grades (silver, lead, zinc, gold) derived from total recorded production. The general form of the model is

$$\log(\text{tons}) = B_0 + \sum[B_i \log M_i] + e$$

where M_i represent gold, zinc, silver, copper, and lead. Logarithmic transformations are necessary to produce near-normal probability density functions. These data were treated by a multiple regression package which is available through the University of British Columbia Computing Centre. In particular, the backwards stepwise option was used, which rejects variables whose regression coefficients cannot be distinguished from zero at a specified level of significance ($\alpha = 0.05$, in this case).

SLOCAN (SANDON) CAMP

Slocan mining camp has been an important silver producing region since the Nineteenth Century. More than 200 individual silver-lead-zinc-gold veins are known from which some production has been obtained (Orr and Sinclair, 1971). These deposits have been divided into two groups for purposes of quantitative modelling (Sinclair, 1982). The western two-thirds of the camp provided a training set (138 deposits) with which quantitative models were established as summarized in Table 1. These models were then used to estimate potential of deposits in the eastern group for which production tonnages were known. An example is shown plotted on Figure 132, where the scatter is comparable to the standard error of the model. Such a result provides validity for the general approach. Unfortunately, calculated tonnage by the four-variable model could be compared with only 19 known production tonnages because gold contents were not recorded for most of the 65 deposits in the eastern group. Obviously, gold is an important component in such a model (compare standard errors of the two models in Table 1).

TABLE 1
SLOCAN (SANDON) REGRESSION MODELS

A: $\text{Log (tons)} = 1.3789 - 1.1459 \log (\text{Au}) - 0.5544 \log (\text{Pb})$
$R^2 = 0.59$
$S_e = 0.8608$
$n = 62$

B: $\text{Log (tons)} = 5.4172 - 1.3907 \log (\text{Ag}) - 0.3786 \log (\text{Zn})$
$R^2 = 0.22$
$S_e = 1.2490$
$n = 95$

The number of deposits on which to base a model increases dramatically if only three independent variables are considered and gold is the one omitted. However, the resulting model (model B, Table 1) is very unsatisfactory from a practical point of view because of the large standard error and the very low coefficient of variation. It is evident

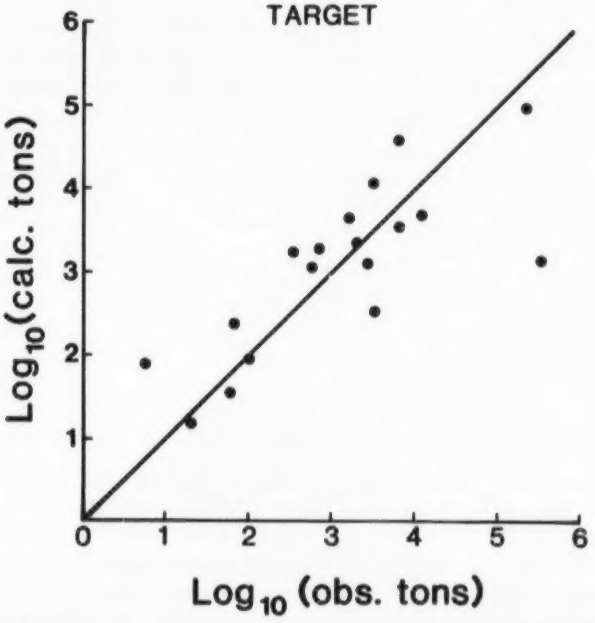


Figure 132. Observed versus calculated tonnages using a multiple regression equation, Slocan camp.

that gold data are highly desirable in such models for Slocan (Sandon) camp. Perhaps the most significant contribution of this study is to stress the importance of gold assays in evaluating vein deposits in Slocan camp.

AINSWORTH CAMP

Of the more than 90 lead-zinc-silver-gold deposits in Ainsworth camp with recorded production, only 13 have average grade information for all four variables. These 'complete' sets of assay data have been used to develop regression model A of Table 2. The multiple regression model has reduced to a simple regression model in this case because lead is a linear combination of other variables and at the 0.05 level silver and zinc were both rejected as not contributing to explaining variability in tons. Clearly gold is an important variable for estimating size potential, but unfortunately is available for few deposits. A much larger data base existed upon which to base a regression model if gold were not included. With this larger data base only zinc was rejected as not contributing to an explanation of the variability of tons. The remaining model (B in Table 2), although statistically meaningful, is of little practical use because of relatively large standard error and low coefficient of variation.

TABLE 2
AINSWORTH REGRESSION MODELS

A: $\text{Log (tons)} = 1.5268 - 0.8068 \log(\text{Au})$
$R^2 = 0.68$
$S_e = 0.6949$
$n = 13$

B: $\text{Log (tons)} = 3.4067 - 0.5770 \log(\text{Ag}) - 0.8011 \log(\text{Zn})$
$R^2 = 0.21$
$S_e = 1.1270$
$n = 49$

SLOCAN CITY CAMP

Slocan City camp contains 74 small polymetallic vein deposits for which production information is available (Orr and Sinclair, 1971). These deposits are scattered throughout an area of about 115 square kilometres. Of these, only 17 have complete production information for tonnage mined and average grades of silver, lead, zinc, and gold. Data for these 17 deposits were used to develop a regression model (A of Table 3). The model is mediocre, but at that, is substantially better than model B (Table 2) which is obtained when gold is omitted.

TABLE 3
SLOCAN CITY REGRESSION MODELS

A: $\text{Log (tons)} = 1.5878 - 0.6085 \log(\text{Au}) - 0.5177 \log(\text{Zn})$

$R^2 = 0.37$

$S_e = 1.0700$

$n = 17$

B: $\text{Log (tons)} = 2.0867 - 0.4508 \log(\text{Zn})$

$R^2 = 0.14$

$S_e = 1.1290$

$n = 33$

TROUT LAKE CAMP

Four grade variables and production tonnages are available for 17 past producer silver-lead-zinc veins. These data were used to establish the following multiple regression model:

$$\log(\text{tons}) = 3.484 - 1.524 \log(\text{Ag}) - 1.821 \log(\text{Au}) + 1.440 \log(\text{Pb}) - 2.644 \log(\text{Zn})$$

$$R^2 = 0.78$$

$$S_e = 0.867$$

All four grade variables have a significant contribution to the reduction of variance in the model, although silver is the single most important variable. Production data span more than five orders of magnitude; consequently, a model that estimates size with an absolute error less than one order of magnitude may have potential in evaluating well-sampled deposits in the camp. Practical application of the model is limited at the moment because for many deposits production data were not recorded for all four metals; zinc data in particular are deficient.

ZEBALLOS CAMP

Production data for 11 vein deposits from the Zeballos gold camp, Vancouver Island (Hansen and Sinclair, 1984), were used to derive the following model:

$$\log_{10}(\text{tons mined}) = 3.09 - 0.97 \log_{10}(\text{Ag}) - 1.67 \log_{10}(\text{Cu})$$

$$R^2 = 0.98$$

$$S_e = 0.41$$

where tons mined is short tons of recorded production, and silver and copper are average grades of recorded production in ounces per short ton and per cent respectively. The backwards stepwise procedure removed two potential grade variables, gold and lead, from the model at the 0.05 level.

DISCUSSION

The five examples cited here demonstrate a procedure for developing useful quantitative (regression) models to evaluate size or relative value of polymetallic vein deposits. Each of the examples involves four independent grade variables. Experience with one, two, or three independent variables is that the resulting models have substantially larger standard errors than is the case with four independent variables.

In four cases the calculated models involve silver-gold-lead-zinc deposits. At the fifth camp the metals are gold-silver-lead-copper. The models differ dramatically from one camp to another, a difference that is accented by considering the most important single variable in reducing variance in the model. At Zeballos the important element, copper, is correlated negatively with tonnage. In Slocan (Sandon) and Ainsworth camps, gold is by far the most significant independent variable and is also negatively correlated with tons. Silver is important in Trout Lake camp, and is correlated positively with size.

The regression model approach suggests a variety of practical applications:

(1) The small number of deposits in a camp that depart most from the model may be anomalous. Of particular interest are those deposits with low observed tonnages and very much higher calculated tonnages. Such deposits may fit the model and have relatively large undiscovered tonnages.

(2) In each camp there are a large number of past producers for which fewer than four metal grades were recorded. In some cases resampling of old workings is possible and such samples, analysed for four variables, could be evaluated by the regression model. Such a program would appear especially viable in the case of Slocan (Sandon) camp where about 270 past producers are known, only 89 of which have data for all four independent variables of the regression model.

(3) Newly found deposits evaluated by drilling, surface and/or underground sampling may have sufficient data so that weighted mean grades can be substituted in the model for rough estimates of size potential. Of course past producers also can be re-evaluated in this way as additional data become available.

The principal difficulty with the method lies in the substantial amount of information necessary to establish the models. Even in camps with many deposits and a long history of production, much of the production may not have been analysed for enough variables or the appropriate variables to provide an acceptable model. Our work demonstrates that different variables are important in different camps. Furthermore, the most important variable for purposes of estimating tonnage may be of relatively minor economic importance with the result that little or no attention is paid to measuring it. This is true of copper in Zeballos deposits and gold in deposits of the Slocan (Sandon) and Ainsworth camps.

CONCLUSIONS

Multiple regression models relating production tonnages to average grades of production for deposits from polymetallic vein camps appear to have potential as a deposit evaluation technique. In the five camps studied here the models provide tonnage estimates with an error of about one order of magnitude or less, in some cases much less. This error is large, but in the context of range of deposit sizes (commonly over five to seven orders of magnitude) the models can discriminate between small tonnage and large tonnage extremes. In addition, the models provide a basis for a probabilistic approach concerning the chances a deposit has of exceeding a 'minimum conceptual target.'

Despite limitations of the availability of data, the regression method appears to have potential in evaluating new finds in established mining camps and in re-evaluating known deposits for which more comprehensive assay information becomes available.

ACKNOWLEDGMENTS

This project began with the efforts of J.F.W. Orr (deceased) in establishing comprehensive mineral deposit files for Ainsworth, Slocan (Sandon), and Slocan City mining camps. M. Hansen did the same for Zeballos camp, as did P. B. Read for the Trout Lake camp. Assistance in computer file editing was provided by A. Bentzen, who also supplied a prodigious amount of computer output. Financial support for this study was provided by the Geological Survey of Canada, the British Columbia Ministry of Energy, Mines and Petroleum Resources, and the British Columbia Science Council.

REFERENCES

Davidson, R. A. (1972): A Computer Oriented Analysis of Metal Production from Ainsworth Mining Camp, Southeastern British Columbia, B.A.Sc. thesis, *Univ. of British Columbia*.

Godwin, C. I. and Sinclair, A. J. (1979): Application of Multiple Regression Analysis to Drill Target Selection, Casino Porphyry Copper-molybdenum Deposit, Yukon, Canada, *Trans. Inst. Min. Met.*, Sec. B, Vol. 88, pp. B93-B106.

Goldsmith, L. B. (1984): A Quantitative Analysis of Some Vein-type Mineral Deposits in Southern British Columbia, unpub. M.Sc. thesis, *Univ. of British Columbia*.

Goldsmith, L. B. and Sinclair, A. J. (1983): Spatial Density of Silver-lead-zinc-gold Vein Deposits in Four Mining Camps in Southeastern British Columbia, *B.C. Ministry of Energy, Mines & Pet. Res.*, Fieldwork, 1982, Paper 1983-1, pp. 251-265.

Goldsmith, L. B. and Sinclair, A. J. (1984): Triangular Graphs as an Aid to Metallogenic Studies of Polymetallic Vein Deposits, *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1983, Paper 1984-1, pp. 240-245.

Hansen, M. C. and Sinclair, A. J. (1984): A Preliminary Assessment of Zeballos Mining Camp, *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1983, Paper 1984-1, pp. 219-232.

Kelly, A. M. and Sheriff, W. J. (1969): A Statistical Examination of the Metallic Mineral Resources of British Columbia, Proc. Symp. on Decision Making in Mineral Exploration II, A. M. Kelly and A. J. Sinclair editors, *Univ. of British Columbia*, pp. 221-243.

Orr, J.F.W. (1971): Mineralogy and Computer-oriented Study of Mineral Deposits in Slocan City Camp, Nelson Mining Division, British Columbia, M.Sc. thesis, *Univ. of British Columbia*.

Orr, J.F.W. and Sinclair, A. J. (1971): Mineral Deposits in the Slocan and Slocan City Areas of British Columbia, *Western Miner*, February, pp. 22-34.

Read, P. B. (1976): Lardeau West Half, *Geol. Surv., Canada*, Open File Map 462, Open File Rept. 464.

Sinclair, A. J. (1979): Preliminary Evaluation of Summary Production Statistics and Location Data for Vein Deposits, Slocan, Ainsworth, and Slocan City Camps, Southern British Columbia, *in* Current Research, Part B, *Geol. Surv., Canada*, Paper 79-1B, pp. 173-178.

.... (1982): Multivariate Models for Relative Mineral Potential, Slocan Silver-lead-zinc-gold camp, *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1981, Paper 1982-1, pp. 167-175.

Sinclair, A. J. and Hansen, M. C. (1983): Resource Assessment of Gold-quartz Veins, Zeballos Mining Camp, Vancouver Island - A Preliminary Report, *Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1982, Paper 1983-1, pp. 290-303.

Sinclair, A. J. and Woodsworth, G. J. (1970): Multiple Regression as a Method of Estimating Exploration Potential in an Area near Terrace, British Columbia, *Econ. Geol.*, Vol. 65, No. 8, pp. 998-1003.

VARIATION OF K/Rb RATIO IN THE MAJOR UNITS OF THE GUICHON CREEK BATHOLITH

(92I)

By A. R. Tombale and A. J. Sinclair
Department of Geological Sciences, University of British Columbia
and
W. J. McMillan
British Columbia Ministry of Energy, Mines and Petroleum Resources

INTRODUCTION

Close geochemical association of potassium and rubidium has led to the extensive use of K/Rb ratios in petrogenetic analysis of igneous systems. Ionic radii of the two elements do not differ by more than 15 per cent (K^+ = 1.33A and Rb^+ = 1.47A), and rubidium as a minor element substitutes extensively for K^+ sites in potassium-bearing minerals, especially in micas, in which K^+ sites are larger than in feldspars. Because of its geochemical similarity to potassium, the distribution of rubidium during magmatic processes is controlled mainly by the availability of K^+ sites. Being larger in size, rubidium accumulates in residual melts more rapidly than does potassium. Hence, with progressive differentiation the K/Rb ratio of rocks should decrease with increasing acidity. Therefore K/Rb ratios can indicate the extent or direction of differentiation in a suite of igneous rock. The K/Rb ratio of oceanic volcanic rocks decreases from 1 300 in oceanic tholeiites to about 350 in alkali basalts and is as low as 300 in trachytes (Engel, *et al.*, 1965). In orogenic andesites the K/Rb ratio also decreases with increasing potassium or acidity (Gill, 1978). For crustal rocks the K/Rb ratios range from 130 to 300 (Taylor, 1965).

The K/Rb ratio in igneous rocks can be used to recognize different magmatic processes that may have affected a particular suite; for example, processes related to source or parent magma and the extent and trend of magmatic differentiation.

Here we consider the distribution of K/Rb ratios in rocks of the Guichon Creek batholith. Since major element chemistry, field evidence, and phase equilibria show that the Guichon Creek batholith is a highly differentiated composite body ranging from quartz-diorite at the margin to quartz monzonite in the core (Northcote, 1969; McMillan, 1976; and others), the K/Rb ratio would be expected to decrease with increasing acidity. However, the K/Rb ratios of Guichon rocks do not follow this expected trend; instead, the ratio increases with increasing acidity (Fig. 133). Few similar K/Rb ratio trends have been reported in the literature, one example being the Blue Mountain nepheline syenite in Ontario (Payne and Shaw, 1967). As well as the anomalous trend, K/Rb

TABLE 1
VARIATION OF POTASSIUM (in weight per cent) AND RUBIDIUM (in ppm), AND K/Rb RATIO IN GUICHON CREEK BATHOLITH ROCKS

	SiO_2	K	Rb	K/Rb	K*	Rb*	K/Rb*	K**	Rb**	K/Rb**
Border Phase	58.9	1.33	39	341	1.66	33	503	1.78	38	468
Guichon Variety	61.8	1.73	52	333	2.01	48	419	1.80	38	474
Chataway Variety	64.2	1.75	47	372	2.01	50	402	1.81	37	489
Bethlehem Phase	65.2	1.85	38	487	1.89	47	402	1.93	38	509
Bethsaida Phase	73.7	2.83	34	832	2.70	73	370	1.89	37	511

NOTE: Starred columns contain values calculated from the Rayleigh fractionation model.
*values represent K, Rb, and K/Rb ratio calculated using the actual modal mineralogy of Guichon batholith rocks
**values are from adjusted mineralogy to produce the K/Rb ratio trend of batholith rocks

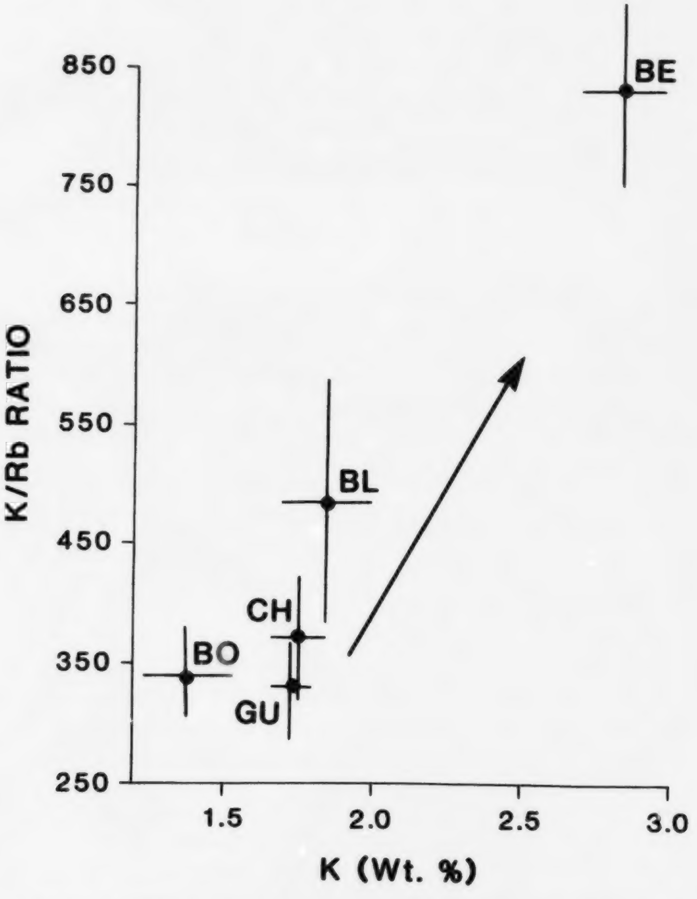


Figure 133. A plot of average K/Rb ratios of major units of the Guichon Creek batholith versus K (weight per cent).

ratio levels are abnormally high in the Guichon Creek batholith, ranging from 300 to over 800 (Table 1). Expected ranges of K/Rb ratios calculated from theoretical concentrations of potassium and rubidium using equilibrium fractionation models (Table 1) are narrower. Thus the range of the K/Rb ratio and its anomalous trend probably indicates the activity of processes other than crystal fractionation.

K/Rb RELATIONS IN GUICHON CREEK BATHOLITH ROCKS

Compositionally, the Guichon Creek batholith parent magma was approximately andesite, with SiO_2 about 63 weight per cent. The large lithophile elements, such as rubidium, show a very wide range of values in andesitic and other calc-alkaline rocks, dependent mostly on the source of the parent magma. For the Guichon Creek batholith average rubidium abundances range from 52 ppm in the Guichon variety to 34 ppm in the Bethsaida phase. The pattern is shown on Figure 134, which also shows that, in general, rubidium increases within phases as silica increases. This contrasts with the general trend for the batholith, where rubidium decreases as silica increases.

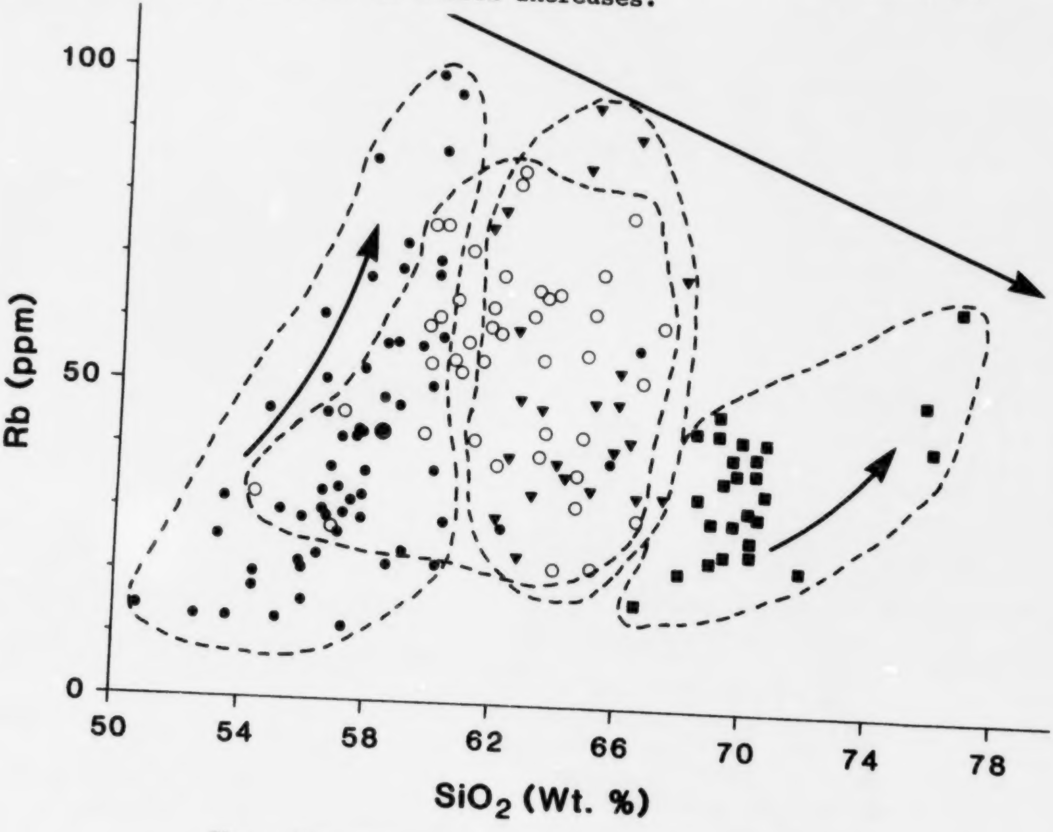


Figure 134. Rb versus SiO_2, Guichon Creek batholith.

DISCUSSION

Several mechanisms have been suggested that could fractionate potassium and rubidium and lead to an increase in K/Rb ratio with progressive differentiation:

(1) mica crystallization,
(2) olivine, clinopyroxene, and garnet crystallization (Jakes and White, 1970),
(3) amphibole crystallization (Harts and Aldrich, 1967), and
(4) the effect of an aqueous phase (Payne and Shaw, 1967).

TABLE 2
ORIGINAL MODAL MINERALOGY USED IN CALCULATING K/Rb TREND

Minerals	Border Phase	Guichon Variety	Chataway Variety	Bethlehem Phase	Bethsaida Phase
Plagioclase	55	50	54	49	52
K-feldspar	3	10	11	10	11
Quartz	18	18	21	21	29
Biotite	7	9	5	3	6
Hornblende	10	8	7	4	0.4
K/Rb	503	419	402	402	370

MINERAL MODES AFTER PROPORTIONS WERE ADJUSTED TO PRODUCE K/Rb TREND OF BATHOLITHIC ROCKS

Minerals	Border Phase	Guichon Variety	Chataway Variety	Bethlehem Phase	Bethsaida Phase
Plagioclase	50	50	50	48	50
K-feldspar	3	10	7	7	6
Biotite	9	6	3	2	2
Hornblende	38	34	40	43	42
K/Rb	468	474	489	509	511

Considering these possible mechanisms, the second does not apply to the Guichon Creek batholith because the minerals specified are either not present or occur as very minor phases. Processes (1) and (3) were modelled theoretically using distribution coefficients of andesitic rocks for these elements. The distribution coefficients of potassium and rubidium used in modelling are 5.63 and 3.26 in biotites and 0.33 and 0.014 in hornblende respectively (Philpotts and Schnetzler, 1970). From these figures, comparative K/Rb ratios are about 2 for biotite and 23 for hornblende. Therefore, mica fractionation could not lead to any appreciable increase in K/Rb ratio, and cannot account for the observed K/Rb variation of the Guichon rocks. With a larger K/Rb ratio, variation in amphibole content could indeed lead to systemic changes in K/Rb ratio. However, the changes in modal mineralogy of Guichon Creek rocks needed to produce the observed trend requires much higher fractions of amphibole than are observed (Table 2). This data suggests that changes in the K/Rb ratio in Guichon rocks could reflect the result of the combined biotite-hornblende fractionation but requires some other process to account for the magnitude of the changes. Process (4), the effect of an aqueous phase, may be the cause. The effect of an aqueous phase is very difficult to document quantitatively because distribution coefficients for potassium and rubidium between silicate melt and an aqueous phase are not available. However, the relative distribution of these two elements can be inferred from their general chemistry. Rubidium has lower melting and boiling points than potassium. Hence, rubidium gasifies more readily than potassium [$Rb_{(s)}>Rb_{(g)}$] and enters the volatile phase more readily. Thus, development of a vapour phase could cause separation between potassium and rubidium. The more ready partitioning of rubidium into a volatile phase depletes the residual melt of rubidium, causing an increase of K/Rb ratio in the residual melt with progressive crystallization. Because of the behaviour of the volatile phase, rapid formation and release, for example, the K/Rb ratio could vary widely and have high and erratic ratios; both these features are observed in the Guichon Creek batholith.

CONCLUSION

Though experimental verification is needed to confirm empirical evidence about the effects of an aqueous phase on K/Rb ratios in magmatic systems, it seems likely that the value and trend of the ratio can be used to indicate whether there was volatile phase activity in the magma. For the Guichon Creek batholith, the trend of K/Rb ratios suggests that the magma contained a high water content that resulted in early saturation; hence, the K/Rb ratio is an indirect indicator of relative degree of differentiation. In the Guichon Creek batholith, the initial water content is estimated to have been between 2 and 3 weight per cent. Saturation was reached after about 72 per cent crystallization, which coincides with completion of crystallization of the Highland Valley phase. The timing of volatile phase release during magmatic differentiation is consistent with that determined independently based on zoning in plagioclase (Westerman, 1970) and formation of dykes, breccias, and mineral deposits (McMillan, 1976).

ACKNOWLEDGMENTS

This work represents part of a Master's thesis by the senior author in the Department of Geological Sciences, University of British Columbia, and was a cooperative study with the British Columbia Ministry of Energy, Mines and Petroleum Resources. All analyses were carried out by the Ministry's laboratory. Funding was provided to A. J. Sinclair by the Canadian International Development Agency.

REFERENCES

Engel, A.E.J., Engel, C. G., and Havens, R.G. (1965): Chemical Characteristics of Oceanic Basalts and the Upper Mantle, *Geol. Soc. Amer.*, Bull., Vol. 76, pp. 719-734.

Ewaert, A. and Stipp, J. J. (1968): Petrogenesis of the Volcanic Rocks of the Central North New Zealand as Indicated by a Study of $^{87}Sr/^{86}Sr$ Ratios and Sr, Rb, K, U and Th Abundances, *Geochim. et Cosmochim. Acta*, Vol. 32, pp. 699-736.

Gast, P. W. (1965): Terrestial Ratio of Potassium to Rubidium and the Composition of the Mantle, *Science*, Vol. 147, p. 858.

Gill, J. B. (1978): Role of Trace Elements Partition Coefficients in Models of Andesite Genesis, *Geochim. et Cosmochim. Acta*, Vol. 42, pp. 709-724.

Hanson, G. N. and Longmuir, D. H. (1978): Modelling of Major Elements in Mantle-melt Systems Using Trace Elements Approaches, *Geochim. et Cosmochim. Acta*, Vol. 42, pp. 725-741.

Hart, S. R. and Aldrich, L. T. (1967): Fractionation of Potassium/rubidium by Amphiboles: Implications Regarding Mantle Composition, *Science*, Vol. 155, pp. 325-327.

Heier, K. S. (1966): Some Crystallo-chemical Relations of Nephelines and Feldspars of Stjesnoy, North Norway, *Jour. Petrol.*, Vol. 7, pp. 95-113.

Jakes, P. and White, A.J.R. (1970): K/Rb Ratio of Rocks from Island Arcs, *Geochim. et Cosmochim. Acta*, Vol. 34, pp. 849-856.

Lange, I. M., Reynolds, R. C., and Lyons, J. B. (1966): K/Rb Ratios in Coexisting K-felspars and Biotites from some New England Granites and Metasediments, *Contr. Mineral. Petrol.*, Vol. 1, pp. 317-322.

McMillan, W. J. (1976): Geology and Genesis of the Highland Valley Ore Deposits and the Guichon Creek Batholith, *in* Porphyry Deposits of the Canadian Cordillera, A. Sutherland Brown, editor, *C.I.M.*, Special Vol. 15, pp. 85-104.

Mittlefehldt, D. W. and Miller, C. F. (1983): Geochemistry of the Sweetwater Wash Pluton, California: Implications of Anomalous Trace Elements Behaviour During Differentiation of Felsic Magmas, *Geochim. et Cosmochim. Acta*, Vol. 47(1), pp. 109-124.

Northcote, K. E. (1969): Geology and Geochronology of the Guichon Creek Batholith, *B.C. Ministry of Energy, Mines & Pet. Res.*, Bull. 56, 73 pp.

Olade, M. A. and Fletcher, W. K. (1975): Primary Dispersion of Rubidium and Strontium Around Porphyry Copper Deposits, Highland Valley, British Columbia, *Econ. Geol.*, Vol. 70, pp. 15-21.

Payne, J. G. and Shaw, D. M. (1967): K/Rb Relations in the Blue Mountain Nepheline Syenite, *Earth Planet. Sci. Lett.*, Vol. 2, pp. 290-292.

Philpotts, J. A. and Schnetzler, C. C. (1970): Phenocryst-matrix Partition Coefficients for K, Rb, Sr, and Ba with Applications to Anorthosite and Basalt Gneiss, *Science*, Vol. 147, pp. 858-860.

Ringwood, A. E. (1955): The Principles Governing Trace Elements Behaviour during Magmatic Crystallization, Part II, The Role of Complex Formation, *Geochim. et Cosmochim. Acta.*, Vol. 7, pp. 242-254.

Shaw, D. M. (1968): A Review of K/Rb Fractionation Trend by Covarience Analysis, *Geochim. et Cosmochim. Acta*, Vol. 32, pp. 573-601.

Taylor, S. R. (1965): The Application of Trace Element Data to Problems in Petrology, *Phys. & Chem. Earth*, Vol. 6, pp. 133-213.

Tombale, A. R. (1984): An Interpretation of Lithogeochemical Data of the Guichon Creek Batholith, unpub. M.Sc. thesis, *Univ. of British Columbia*, 141 pp.

Westerman, C. J. (1970): A Petrogenetic Study of the Guichon Creek Batholith, British Columbia, unpub. M.Sc. thesis, *Univ. of British Columbia*.

White, A.J.R. (1966): Genesis of Migmatites from the Palmer Region of South Australia, *Chem. Geol.*, Vol. 1, pp. 165-200.

SHOSHONITES AND ASSOCIATED ROCKS
OF CENTRAL BRITISH COLUMBIA

By Andrée Spence
Department of Geological Sciences, University of British Columbia

INTRODUCTION

The belt of Upper Triassic volcanic sequences of central British Columbia has long been recognized to contain a mixture of alkaline potassic, alkaline sodic, as well as calc-alkaline suites. A similar association is also found in the Lower Jurassic sequences that occur within this belt and in the Eocene sequences of the Ootsa Lake-White Lake belt.

This paper demonstrates, and in some cases confirms, the shoshonitic nature of the alkaline potassic suites of Upper Triassic, Lower Jurassic, and Eocene age. Interest in the recognition of such volcanism was prompted at first by the identification, from chemical data, of shoshonitic lenses (Basic Schist Unit of Thorstad, 1983) intruding, or interlayered with, the arc tholeiitic Kutcho Creek Formation and by the subsequent preliminary examination of data from Upper Triassic and Lower Jurassic sequences as part of a general review of the chemical composition of volcanic sequences in British Columbia.

A brief bibliographic review of the shoshonitic association in the world, followed by the chemical pattern of these shoshonites obtained from certain petrologic diagrams, serve as an introduction to the review of shoshonitic associations of central British Columbia. The latter include suites from the Upper Triassic Stuhini, Takla, and Nicola Groups; the Lower Jurassic Toodoggone, Horsefly, and Rossland sequences; and a few sequences from the Eocene Kamloops and Penticton Groups. Emphasis is placed on shoshonites for petrological, tectonic, and economic reasons: (1) shoshonites, once considered a petrological oddity, have gained full petrological status - at least amongst island arcs petrologists - since so many shoshonitic suites have been recognized in arcs of the southwest Pacific, Italy, Puerto Rico, and Kamtchatka; (2) they reflect collision periods and disturbance of subduction zones and therefore may shed light on the collision history of allochthonous terranes of central British Columbia; (3) associated copper and gold deposits occur commonly as epigenetic vein systems in the shoshonitic volcanic piles and as porphyry copper-gold in comagmatic alkaline intrusions.

THE SHOSHONITIC ASSOCIATION

Shoshonite, together with shonkinite, absarokite, and banakite, were described and named by Iddings (1895) in the Eocene units of Yellowstone Park. About the same time, Washington (1897, 1906) described the ciminite-vulsinite-toscanite series and associated leucitic rocks of western Italy, and Ransome (1898) the latite series of Sierra, Nevada. All these series are equivalent and belong to the shoshonite association. Johannsen (1938), however, thought that these terms represented petrological oddities and should be discarded; Streckeisen (1967) ignored them. In 'Alkaline Rocks' (Sorensen, 1974) only shonkinite is briefly mentioned and nothing is said about alkaline rocks of island arcs.

The chemical and tectonic importance of shoshonites as the product of a specific alkaline potassic magma were recognized by Joplin (1964, 1965, 1968) while comparing rocks from Australia; Yellowstone Park; Sierra, Nevada; Italy; and Indonesia. She pointed out the characteristic value of the ratio $K_2O/Na_2O \geqslant 1$, the low Ti content and the high Al content occurring with Ca and Mg abundances similar to subalkaline rocks (in spite of the very high potash content). She proposed the terms 'shoshonite association' to encompass an alkaline potassic series from basalt to rhyolite, trachyte, and phonolite, depending on the degree of silica saturation, and divided it into two groups (1) 'near-saturated' including shoshonites *sensu stricto*, alkaline rhyolite, and trachyte, and (2) 'undersaturated' including the rarer leucitic rocks. Joplin also pointed out that this particular type of volcanism occurred at a time of stabilization, at the close of a period of active tectonism. Nicholls and Carmichael (1969), on the other hand, thought that it was unnecessary to elevate the shoshonitic association to a special status.

Subsequently, numerous studies documented the existence of shoshonites in Fiji (Dickinson, 1968; Gill, 1970), New Hebrides (Gill and Gorton, 1971), Papua-New Guinea (Jakes and White, 1969; Johnson, 1971; Mackenzie and Chappell, 1972; Smith, 1972), Solomon Islands (Hackman, 1971), Italy (Appelton, 1972; Ninkovich and Hays, 1972; Barbieri, *et al.*, 1974), and Puerto Rico (Jolly, 1971).

These studies substantiate the validity of Joplin's chemical distinction and its tectonic significance. All authors, Ninkovich and Hays excepted, attribute the generation of shoshonites to collision of plates resulting in the disturbance of the subduction zone, its 'jamming' and, in some cases, its reversal.

To the shoshonitic association of volcanic rocks and associated comagmatic intrusive rocks defined by Joplin, one must add the alkaline ultramafic intrusions of Alaskan type. In Alaska, Irvine (1973) demonstrated that the alkaline picritic potassic basalts of Bridget Cove could be the source (by crystal settling) of the nearby alkaline ultramafic intrusions of Early Cretaceous age. Similarly, he linked the Upper Triassic alkaline ultramafic intrusions of British Columbia to the surrounding more differentiated volcanic rocks of the Takla Group (Irvine, 1976). It seems, however, that these volcanic rocks, and hence the related Alaskan-type ultramafic intrusions, were recognized as belonging to the newly established shoshonitic association only by Delong (1975) for the Briget Cove basalts and by Meade (1977) for the Takla volcanics.

High-K calc-alkaline volcanism commonly precedes or is associated with shoshonites (Eolian Islands, Papua-New Guinea, New Hebrides, Fiji). A complete gradation from high-K andesites to shoshonites and a similar trace-element signature throughout the series were documented by Mackenzie and Chappell (1972). In areas devoid of recognized shoshonites, the presence of high-K andesites may imply similar tectonic conditions.

NOMENCLATURE AND CHEMICAL PROFILE

The petrographic nomenclature is complex and confusing as it reflects the original definitions given to similar rock types by several authors (*see* Joplin, 1968). As a result, some authors even reject specific names in favour of the more general terms. The nomenclature given in Table 1 is that of Mackenzie and Chappell (1972) for the shoshonites of the Highlands of New Guinea, to which trachyte and liparite have been added. This nomenclature applies only for the 'near-saturated' group. For the rarer 'undersaturated' group, Appleton's classification for the leucitic rocks of the Roman Province is used.

TABLE 1
NOMENCLATURE OF THE NEAR-SATURATED ASSOCIATION

SiO_2 Range	Name	Includes	General Name
<50%	Absarokite	Ciminite	Trachybasalt
50-57%	Shoshonite	Banakite	Trachybasalt
		Latite	Low-Si Trachyandesite
		Vulsinite	
57-63%	Latite	Q banakite	High-Si trachyandesite
	$K_2 < 6\%$	Vulsinite	Trachyte
	High-K trachyte		
	$K_2 < 6\%$		
>63%	Toscanite	Q latite	Alkaline dacite
	Liparite		Alkaline rhyolite

Shoshonites were described by Joplin as having $K_2O/Na_2O \geqslant 1$, together with high Al, Ca, and Mg and low Ti. Mackenzie and Chappell (1972) proposed $K_2O/Na_2O \geqslant 0.6$ for 50 per cent SiO_2 and $\geqslant 1$ for 56 per cent SiO_2. This classification holds for most shoshonites except for those of Bufumbira (Uganda) which have a high Ti content. More importantly, there are other alkaline potassic rocks with similar K_2O/Na_2O ratios, which do have leucitic members, and with which shoshonites may be and have been confused. These fall into two unrelated groups: potasso-sodic (including the kamafugites) and orenditic.

The variation diagrams used were MgO, CaO, Na_2O, K_2O, Alk, FeO_T, and Al_2O_3, as well as TiO_2 versus FeO_T. Specific compositional domains have been defined on all except Al_2O_3:SiO_2 as illustrated for the Upper Triassic suites on Figures 135 to 143 (pages 438 to 442).

All three potassic series were found to plot in the alkaline domain of Alk versus SiO_2 (Kuno's boundary), and in the very high-K (VHK) and extreme high-K (EHK) domains of K_2O versus SiO_2; most are in the subalkaline domain on MgO versus SiO_2. All three series also show regular decrease in Fe content and a steep increase from 10 to 12 per cent Al_2O_3 in picritic basalts and up to 22 per cent for some trachytes and phonolites of the shoshonitic and potasso-sodic series. An Al_2O_3 decrease appears only for latites and rhyolites. Orenditic suites have typically lower Al_2O_3 contents, increasing from 7 to 12 per cent.

Titanium was found to be characteristic of the tectonic setting just as in subalkaline basalts. On TiO_2 versus FeO_T, shoshonitic and potasso-sodic basalts of island arcs and continental margins plot in the low-Fe part of the island arc and ridge domains (these domains were defined for subalkaline basalts), whereas the continental and oceanic potasso-sodic suite, as well as the continental Bufumbira shoshonites, plot in the within-plate domain. Orenditic suites are all in the within-plate domain.

Shoshonitic and potasso-sodic series are best separated by their Na content. Shoshonitic series fall within the subalkaline domain on Na_2O:SiO_2, whereas the potasso-sodic series are above it. In addition, Ca content of shoshonitic series tend to be higher: CaO values are mainly in the subalkaline domain, though those of the more undersaturated suites are below it, whereas all potasso-sodic suites plot below, or at best straddle, the lower subalkaline boundary.

Orenditic series differ from the shoshonites by their lower Al_2O_3 contents; in the critial 10 to 12 per cent Al_2O_3 range, orendites are markedly more potassic.

SHOSHONITES OF BRITISH COLUMBIA

The suites examined include: (1) the Upper Triassic Stuhini Group in the Galore Creek area (Panteleyev, personal communication, 1984; Allen, *et al.*, 1976) and further east, near the Hotailuh batholith (Anderson, 1983), the Takla Group near the Hogem batholith (Meade, 1977), the Nicola Group south of Kamloops (Preto, 1979), and the Basic Schist unit of the Kutcho Creek Foramtion (Thorstad, 1983); (2) the Lower Jurassic Toodoggone volcanics (Schroeter, 1982; Forster, 1984), Horsefly Group (Morton, 1976), and Rossland Group (Daly, 1912; Little, 1960); (3) the Eocene Kamloops Group (Ewing, 1981; Church and Evans, 1983) and the Penticton Group (Church, 1973).

The shoshonitic character of the alkaline potassic suites was recognized by Meade (1977) for the Takla Group (units 7b, 7c, 8) and by Church for the Penticton Group (high-K trachyandesite and trachyte of the 'B' series). At Galore Creek, in the Stuhini Group, Allen *et al.* (197±6) compared the unusual leucitic phonolites and syenites to the Mediterranean and western Alaskan assemblages. Other authors, such as Lefebure (1976) and Preto (1979) for the Nicola Group and Morton (1976) for cycle I of the Horsefly Group, compared them to the potassic volcanics of Gough and Tristan da Cunha Islands which are, however, more sodic and Ti rich, befitting their oceanic setting. Anderson (1983) and Ewing (1981) classified the basalts of the Stuhini and Kamloops Groups as calc-alkaline because of their saturated composition, in spite of their high alkali content. Both authors implicitly define as alkaline, only rocks deficient in silica and therefore eliminate many saturated and oversaturated rocks, and hence many shoshonites, from the alkaline family.

UPPER TRIASSIC

Shoshonites

To simplify and reduce the great number of petrogenetic diagrams, only data from the shoshonitic sequences within the Stuhini, Takla, and Nicola (central belt) Groups were plotted (Figs. 135 to 143) to illustrate their chemical characteristics. The associated subalkaline and alkaline, more sodic, volcanic analyses were omitted deliberately.

The occurrences of the most common alterations, which involve Ca and/or Mg (and therefore Na) were assessed on MgO/CaO diagrams, on which all suites, from calcic to the most alkaline (cumulates excepted), plot in a domain labelled 'unaltered' (de Rosen-Spence, 1976). This domain is narrow enough to make it useful for screening data. Of 71 samples, 40 plot in the 'unaltered' domain, thus providing a sound base for interpreting other diagrams. Twenty-three analyses plot as altered and eight have gained Ca or have plagioclase cumulates. The Nicola shoshonites are by far the most altered with only two 'unaltered' samples among the available analyses.

The MgO content of most samples plot in the 'subalkaline' domain of MgO/SiO_2 (Fig. 136), none above it. There is thus no evidence of extensive Mg metasomatism.

Figures 137 to 139 show that the Upper Triassic potassic volcanics of central British Columbia are unequivocally shoshonites. The CaO content (Fig. 137) of the unaltered samples is equivalent to that of subalkaline rocks. Only the most undersaturated trachybasalts and phonolites of Galore Creek are deficient in CaO. Most altered samples, however, show an expected overall decrease in CaO relative to the unaltered samples.

The Na_2O contents (Fig. 138) of unaltered samples are also similar to those of subalkaline rocks, whereas the K_2O contents (Fig. 139) are much higher, and plot predominantly in the very high-K (VHK) and extreme high-K (EHK) domains. Most of the extreme values belong to the highly undersaturated Upper unit of Galore Creek (Stuhini Group). The few abnormally high and low Na values can be ascribed to replacement of Ca and/or K by Na, and Na by K respectively as the same samples display corresponding low Ca and/or K and extreme high-K values.

The alkaline character, evident on Alk versus SiO_2 (Fig. 140) where Kuno's boundaries are traced, is due mainly to the high K_2O contents. The Irvine-Baragar's boundary would cut across the lower cluster of points giving a false impression of mixed character to British Columbia shoshonitic rocks.

The regular decrease in FeO_T (Fig. 141) and dramatic increase in Al_2O_3 (Fig. 142) are typical of alkaline potassic suites. The plot of TiO_2 values for basalts with $48 \leqslant SiO_2 \leqslant 50.5$, in the island arc domain of TiO_2 versus FeO_T (Fig. 143) confirm the tectonic setting of these shoshonites, which could be surmised from their close association with high-Al and calc-alkaline *sensu stricto* sequences.

All suites, except the Galore Creek Upper unit (Stuhini), belong to the 'near-saturated' group as defined by Joplin. All suites are composed mainly of shoshonites *sensu stricto* accompanied by some absarokites. Latites occur also in the Galore Creek Lower unit (Stuhini) and toscanites have been identified in the Triassic-Jurassic volcanic sequence which overlies the Stuhini Group near the Hotailuh batholith.

The Galore Creek Upper unit is composed mainly of rocks of the 'undersaturated' group, and pseudoleucite has been identified in several flows. The analyses compare well with the least undersaturated rocks of the Roman Province and comprise phonolitic tephrites, tephritic phonolites, and leucite phonolites. A few near-saturated shoshonites are also present.

Associated Rocks

Subalkaline rocks associated with the shoshonites belong to medium-K and high-K calc-alkaline (*sensu stricto*) and high-Al basaltic suites. Their stratigraphic position is uncertain in many cases, and they could interfinger with the shoshonites as in the Toodoggone volcanics and Penticton Group. The following were identified:

(1) medium-K and high-K andesites in the Galore Creek Lower unit;

(2) high-K and high-Al basalts showing Fe enrichment in the Stuhini Group, Hotailuh area;

(3) in the Takla Group, high-K basaltic andesites (unit 4c), probably a time equivalent with the shoshonites (units 7b, 7c, 8); medium-K basalts and basaltic andesites with high-Al (unit 6b) and tholeiitic (unit 7a) affinities below the shoshonites; medium-K calc-alkaline andesite (unit 9c) above the shoshonites, and separated from them by a more sodic alkaline unit (9a); and

(4) in the Nicola Group (central belt), medium-K, high-Al, Fe-enriched, basalts at the alkaline limit are probably the lateral extension of similar andesites and rhyolites of the western belt which are thought to be younger than the shoshonites (Preto, 1979). This high-Al sequence is similar to that of the Newberry volcano which sits behind the Cascades chain.

Alkaline sodic rocks may have medium to very high-K contents and may be nepheline or quartz normative. The tend to follow (with one exception) the shoshonites and separate them from medium-K calc-alkaline volcanism. The following were identified:

(1) in cycle I of Triassic-Jurassic volcanics overlying the Stuhini Group (Hotailuh area): high to very high-K, Ne-normative trachyandesites, associated with shoshonitic toscanites and followed by cycle II comprising medium-K basaltic andesites and dacites;

(2) in the Takla Group: medium to high-K trachybasalts and trachyandesites (units 2, 4a) underlie or are equivalent to the shoshonites; mildly alkaline, quartz-normative andesites (unit 9a) are intermediate between latites and mildly sodic trachyandesites and overlie the shoshonites; and

(3) in the Nicola Group: medium to high-K, Q-normative trachyandesites are associated with shoshonites of the eastern belt; similar comagmatic microdiorites intrude the shoshonites of the central belt.

All associated rocks, whether subalkaline or alkaline, have titanium contents typical of island arcs, with the exception of the high-Al sequence of the Nicola Group which plots in the ridge domain.

LOWER JURASSIC

Shoshonitic sequences, similar to those of Upper Triassic age have been identified amongst the Lower Jurassic sequences which overlie the alkaline Upper Triassic belt previously described. Calc-alkaline and alkaline sodic sequences are also present.

The Toodoggone volcanics are an assemblage of high-K calc-alkaline and shoshonitic lavas and tuffs. In the area sampled by Schroeter (1982) high-K andesites occur with latite flows and are overlain by altered trachyte tuffs. In the area studied by Forster (1984), the sequence is composed of high to near medium-K andesites and dacites with only minor interbedded shoshonitic trachyte. These successions suggest the coexistence of two different volcanic centres erupting concomitantly alkaline and calc-alkaline magmas.

In the Horsefly Group, where Morton (1976) recognized three successive cycles, only cycle I contains absarokites and shoshonites. Cycles II and III are more sodic: cycle II is high-K sodic, and cycle III is very high-K potasso sodic with $K_2O = Na_2O$.

In the Rossland Group (Daly, 1912; Little, 1960) the sequence is composed of shoshonites and latites and had been classified as latitic (Ransome's definition) by Daly.

EOCENE

In the Kamloops Group, the Salmon Arm basalts and andesites (Church and Evans, 1983) and the basalts analysed by Ewing (1981) are potassic and mildly alkaline. They plot as shoshonites leading to an oversaturated trend. Those analysed by Ewing are associated with calc-alkaline andesites and rhyolites.

In the time-equivalent Penticton Group, Church (1973) recognized shoshonitic trachytes (group 'B') interbedded with calc-alkaline andesites and rhyolites (group 'A'), underlain by more sodic alkaline porphyry and phonolite. A few of Church's andesites are shoshonites, less alkaline than the trachytes. In more detail, the Kitley Lake trachyte, Kearns Creek shoshonites, and Nimpit Lake trachytes form a first group, and the White Lake shoshonites and Skaha trachytes a second group, separated by calc-alkaline andesites (Park Rill) and rhyolite (Marama).

TECTONIC AND OTHER IMPLICATIONS

The recognition of the alkaline potassic volcanism in British Columbia as shoshonitic is important for its tectonic significance; shoshonitic volcanism is linked with collision of plates, disturbance, even reversal, and finally dying of a subduction zone. It is therefore most interesting to observe that the Upper Triassic and Lower Jurassic shoshonites occurred during the period of 'docking' of the Stikinia, Cache Creek, Quesnellia, and Eastern terranes and their accretion to North America. The occurrence in a narrow belt of contemporaneous medium-K, high-K, and very high-K volcanism requires a steeply dipping subduction zone during Upper Triassic and Lower Jurassic times. The coexistence during the Lower Jurassic of the narrow Toodoggone-Rossland arc and the wide Hazelton arc to the west, would require a distinct subduction zone for the Hazelton arc.

If the Philippines arcs (Divis, 1980) are taken as a model, one could envisage that the Upper Triassic subduction zone, after being disturbed by the collision of the allochthonous terranes and having generated the calc-alkaline-shoshonitic Nicola-Takla-Stuhini arc as it became subvertical, was eventually reversed during accretion to North America before dying, generating hence the Toodoggone-Rossland arc. At that time a new subduction zone was already operating further west generating the Hazelton arc. This model is intended, of course, to be very general and does not take into account relative north-south motions of the different blocks, nor the possibility that the Upper Triassic arc was actually double, separated by the Cache Creek terrane.

The Eocene shoshonites probably are linked to the disturbance of the subduction zone at their time of formation. Collision of other allochthonous terranes also may have played a role.

The Upper Jurassic-Lower Cretaceous shoshonites of western Alaska also occurred after 'docking' of the Wrangellia and Alexander terranes.

From a practical point of view the abundance of shoshonite and alkali-rich rocks is encouraging to the explorationist. The alkaline character of numerous porphyry-type deposits has been known for many years in the Canadian Cordillera but the possible association of epithermal gold systems with alkali-rich sequences is a much more recent concept.

ACKNOWLEDGMENTS

This paper stems from a study of whole rock chemical data for volcanic sequences in British Columbia undertaken as part of a major project on resource and exploration models in British Columbia, under the supervision of Dr. A. J. Sinclair, University of British Columbia, and funded by the Science Secretariat of British Columbia. Chemical data were accumulated from many sources through the assistance of many people including: J.W.H. Monger, J. Muller, A. Panteleyev, and B. N. Church.

REFERENCES

Allen, D. G., Panteleyev, A., and Armstrong, A. T. (1976): Galore Creek, *in* Porphyry Deposits of the Canadian Cordillera, A. Sutherland Brown, editor, *C.I.M.*, Special Vol. 15, pp. 402-414.

Anderson, R. G. (1983): Geology of the Hotailuh Batholith and Surrounding Volcanic and Sedimentary Rocks, North-central British Columbia, unpub. Ph.D. thesis, *Carleton University*.

Appleton, J. D. (1972): Petrogenesis of Potassium-rich Lavas from the Roccamonfina Volcano, Roman Region, Italy, *Jour. Petrol.*, Vol. 13, pp. 425-456.

Barbieri, F., Innocenti, F., Ferrara, G., Keller, J., and Villari, L. (1974): Evolution of Eolian Arc Volcanism, *Earth Planet. Sci. Lett.*, Vol. 21, pp. 269-276.

Church, B. N. (1973): Geology of the White Lake Basin, British Columbia, *B.C. Ministry of Energy, Mines & Pet. Res.*, Bull. 61.

Church, B. N. and Evans, S. G. (1983): Basalts of the Kamloops Group in the Salmon River Area, British Columbia, *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1982, Paper 1983-1, pp. 89-92.

Daly, R. A. (1912): Geology of the North American Cordillera at the Forty-ninth Parallel, *Geol. Surv., Canada,* Mem. 38.

Delong, S. E. (1975): Ultramafic and Mafic Inclusions, Kanaga Island, Alaska, and the Occurrence of Alkaline Rocks in Island Arcs, *Jour. Geol.*, Vol. 83, pp. 721-736.

de Rosen-Spence, A. F. (1976): Stratigraphy, Development and Petrogenesis of the Central Noranda Volcanic Pile, Noranda, Quebec, unpub. Ph.D. thesis, *University of Toronto*.

Dickinson, W. R. (1968): Laye Cenozoic Shoshonitic Lavas in Northwestern Vitu Levu, Fiji, *Nature*, Vol. 219, p. 148.

Divis, A. F. (1980): The Petrology and Tectonics of Recent Volcanism in the Central Philippine Islands, *in* The Tectonic and Geological Evolution of Southeast Asian Seas and Islands, D. E. Hayes, editor, *Am. Geoph. Union, Geophy. Monograph,* Vol. 23, pp. 127-144.

Ewing, T. E. (1981): Geological and Tectonic Setting of the Kamloops Group, South Central British Columbia, Ph.D. thesis, *University of British Columbia*.

Forster, D. (1984): Geology, Petrology, and Precious Metal Mineralization, Toodoggone River Area, North Central British Columbia, unpub. M.Sc. thesis, *University of British Columbia*.

Gill, J. B. (1970): Geochemistry of Viti Levu and its Evolution as an Island Arc, *Contr. Mineral. Petrol.*, Vol. 27, pp. 179-203.

.... (1981): Orogenic Andesites and Plate Tectonics, *Springer-Verlag*, New York, 390 pp.

Gill, J. B. and Gorton, M. (1971): A Proposed Geological and Geochemical History of Eastern Melanesia, *in* The Western Pacific, P. J. Coleman, editor, *Univ. Western Australia Press*, pp. 543-566.

Gupta, A. K. and Yagi, K. (1980): Petrology and Genesis of Leucite-bearing Rocks, *Springer-Verlag,* New York.

Hackman, B. (1971): The Solomon Fracture Arc, *in* The Western Pacific, P. J. Coleman, editor, *Univ. Western Australia Press*.

Iddings, J. P. (1895): Absarokite-shoshonite-banakite Series, *Jour. Geol.*, Vol. 3, pp. 935-959.

Irvine, T. N. (1973): Bridget Cove Volcanics, Juneau Area, Alaska: Possible Parental Magma of Alaskan-type Ultramafic Complexes, *Carnegie Inst.*, Geophys. Lab. Yearbook, pp. 478-491.

.... (1976): Studies of Cordilleran Gabbroic and Ultramafic Intrusions, British Columbia, *in* Current Research, Part A, *Geol. Surv., Canada*, Paper 76-1A, pp. 75-81.

Irvine, T. N. and Baragar, W.R.A. (1971): A Guide to the Chemical Classification of the Common Volcanic Rocks, *Cdn. Jour. Earth Sci.*, Vol. 8, pp. 523-548.

Jakes, P. and White A.J.R. (1969): Structure of the Melanesian Arcs and Correlation with Magma Types, *Tectonophysics* Vol. 8, pp. 223-236.

Johannsen, A. (1938): A Descriptive Petrography of the Igneous Rocks, *University of Chicago Press*.

Johnson, R. W. (1971): Distribution and Petrology of Late Cenozoic Volcanoes in Papua, New Guinea, *in* The Western Pacific, P. J. Coleman, editor, *Univ. Western Australia Press*, pp. 523-533.

Jolly, W. T. (1971): Potassium-rich Igneous Rocks from Puerto Rico, *Geol. Soc. Am.*, Bull., Vol. 82, pp. 275-294.

Joplin, C. A. (1964): A Petrography of Australian Igneous Rocks, *Angus and Robertston*, Sydney.

.... (1965): The Problem of the Potash-rich Basaltic Rocks, *Mineral. Mag.*, Vol. 34, pp. 266-275.

.... (1968): The Shoshonite Association: A Review, *Geol. Soc. Australia*, Vol. 15, pp. 274, 275.

Kuno, H. (1966): Lateral Variation of Basalt Magma Types Across Continental Margins and Island Arcs, *Bull. Volc.*, Vol. 29, pp. 195-222.

Lefebure, D. V. (1976): Geology of the Nicola Group in the Fairweather Hills, British Columbia, unpub. M.Sc. thesis, *Queen's University*.

Little, H. W. (1960): Nelson Map-area, West Half, British Columbia, *Geol. Surv., Canada*, Mem. 308.

Mackenzie, D. E. and Chappell, B. W. (1972): Shoshonitic and Calc-alkaline Lavas from the Highlands of Papua, New Guinea, *Contr. Mineral. Petrol.*, Vol. 35, pp. 50-62.

Meade, H. D. (1977): Petrology and Metal Occurrences of the Takla Group and Hogem and Germansen Batholiths, North Central British Columbia, unpub. Ph.D. thesis, *University of Western Ontario*.

Morton, R. L. (1976): Alkalic Volcanism and Cu Deposits of the Horsefly Area, Central British Columbia, unpub. Ph.D. thesis, *Carleton University*.

Nicholls, J. and Carmichael, I.S.E. (1969): A Commentary on the Absarokite-shoshonite-banakite Series of Wyoming, U.S.A., *Schweiz. Mineral. Petrog. Mitt.*, Vol. 49, pp. 47-64.

Ninkovich, D. and Hays, J. D. (1972): Mediterranean Island Arcs and Origin of High-potash Volcanoes, *Earth Planet. Sci. Lett.*, Vol. 16, pp. 331-345.

Preto, V. A. (1979): Geology of the Nicola Group between Merritt and Princeton, *B.C. Ministry of Energy, Mines & Pet. Res.*, Bull. 69.

Ransome, F. L. (1898): Some Lava Flows of the Western Slope of the Sierra Nevada, California, *Am. Jour. Sci.*, Vol. 155, pp. 355-375.

Schroeter, T. G. (1982): Toodoggone River Area, *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1981, Paper 1982-1, pp. 122-133.

Smith, I. E. (1972): High-K Intrusives from South-east Papua, *Contr. Mineral. Petrol.*, Vol. 34, pp. 167-176.

Sorensen, H. (1974): Alkaline Rocks, *John Wiley and Sons*, London.

Streckeisen, A. L. (1967): Classification and Nomenclature of Igneous Rocks, *N. Jb. Miner. Abh.*, Vol. 107, pp. 144-240.

Thorstad, L. E. (1983): The Upper Triassic Kutcho Formation, Cassiar Mountains, North-central British Columbia, unpub. M.Sc. thesis, *University of British Columbia*.

Washington, H. S. (1897): Italian Petrological Sketches V, Summary and Conclusions, *Jour. Geol.*, Vol. 5, pp. 346-377.

.... (1906): The Roman Comagmatic Region, *Carnegie Inst.*, Vol. 57, pp. 1-199.

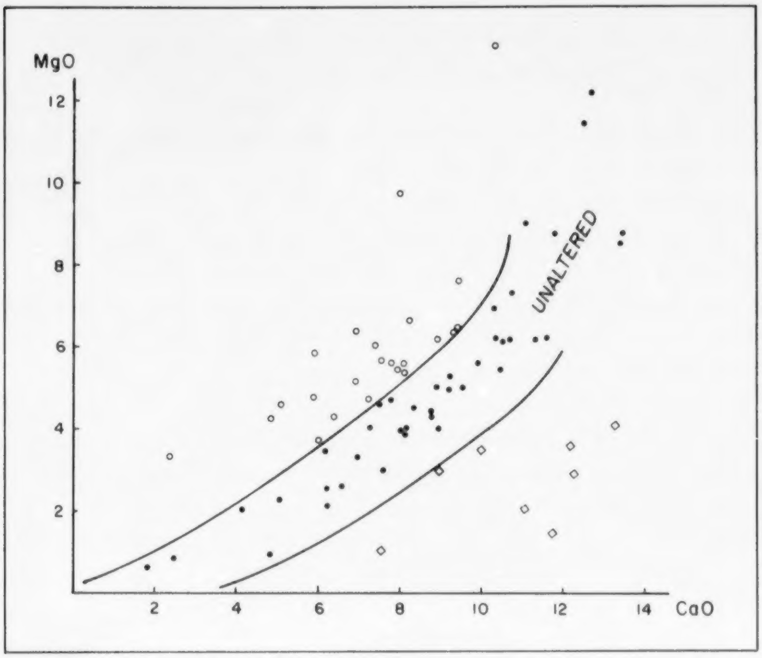


Figure 135. Upper Triassic shoshonites. MgO:CaO plot designed to screen 'unaltered' (filled circles), 'altered' (open circles) samples, and samples with 'added Ca' or plagioclase cumulates (squares). Unaltered domain from de Rosen-Spence (1976).

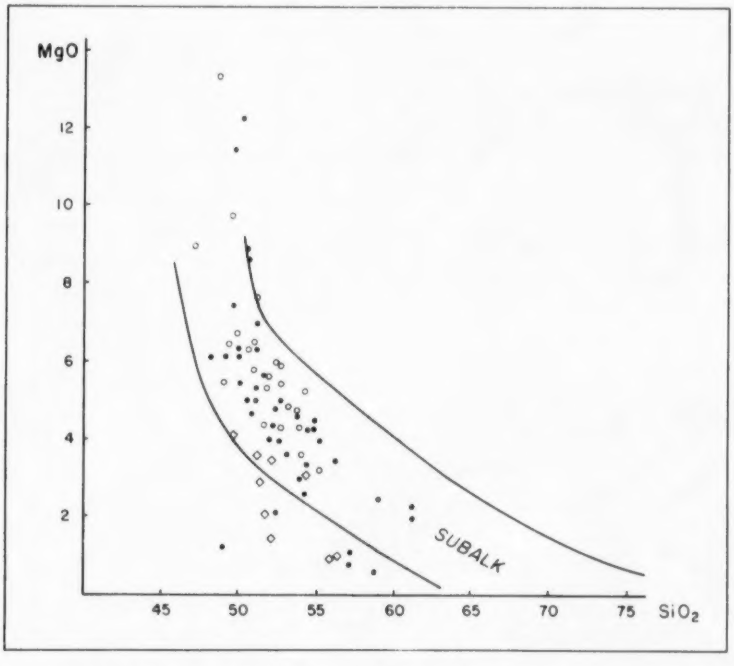


Figure 136. Upper Triassic shoshonites. MgO:SiO_2 plot, notice absence of data points above the 'subalkaline' domain. Boundaries from de Rosen-Spence (1976).

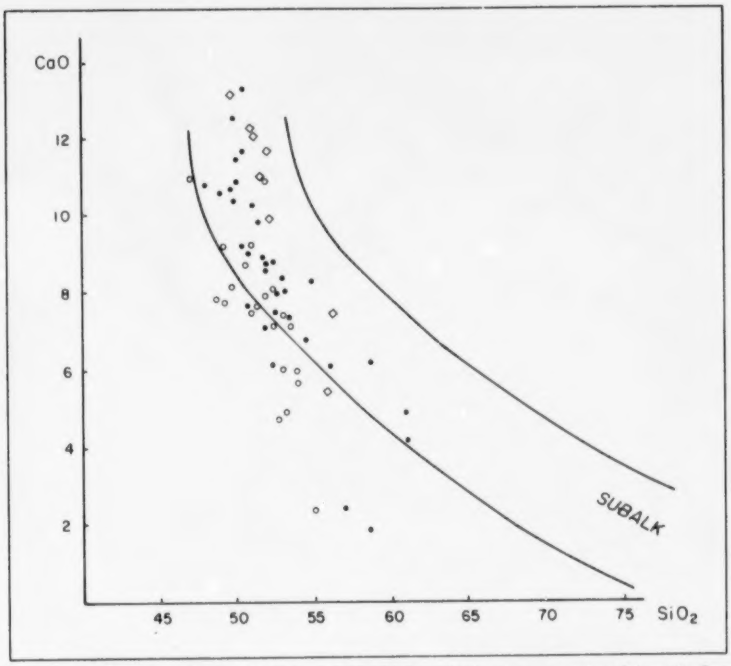


Figure 137. Upper Triassic shoshonites. CaO:SiO_2 plot shows majority of 'unaltered' data points in 'subalkaline' domain. Boundaries from de Rosen-Spence (1976).

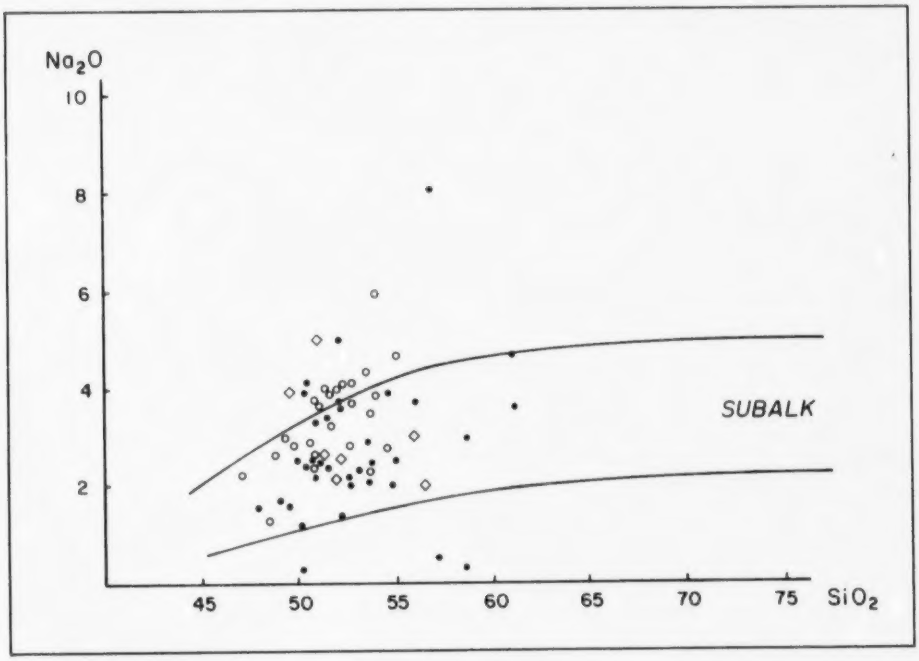


Figure 138. Upper Triassic shoshonites. Na_2O:SiO_2 plot shows most data points in 'subalkaline' domain. Those above it have lower K_2O contents. Boundaries from de Rosen-Spence (1976).

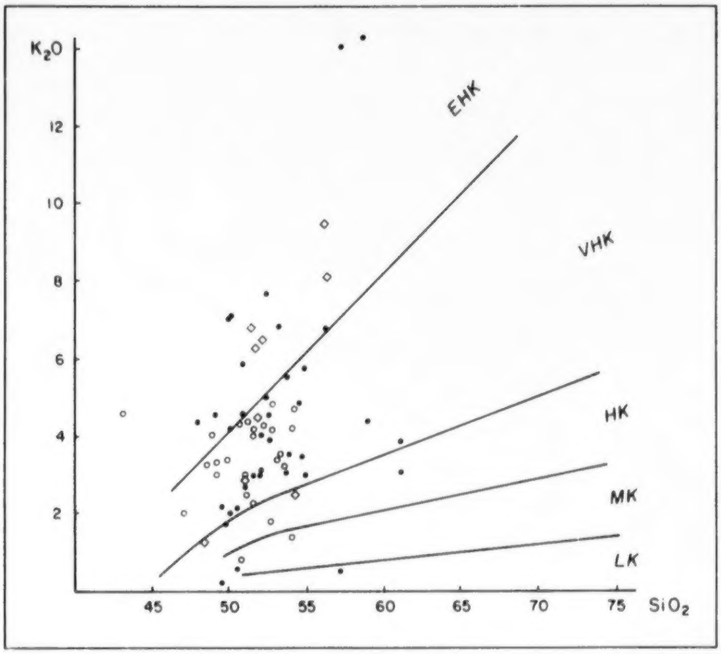


Figure 139. Upper Triassic shoshonites. K_2O:SiO_2 plot illustrates the highly potassic nature of the shoshonites. Points below the 'very high-K' domain correspond to samples with above normal Na_2O on Figure 138. Low (LK), medium (MK), and high (HK) K_2O domains from Gill (1981); very high (VHK) and extreme high (EHK) K_2O domains from this study.

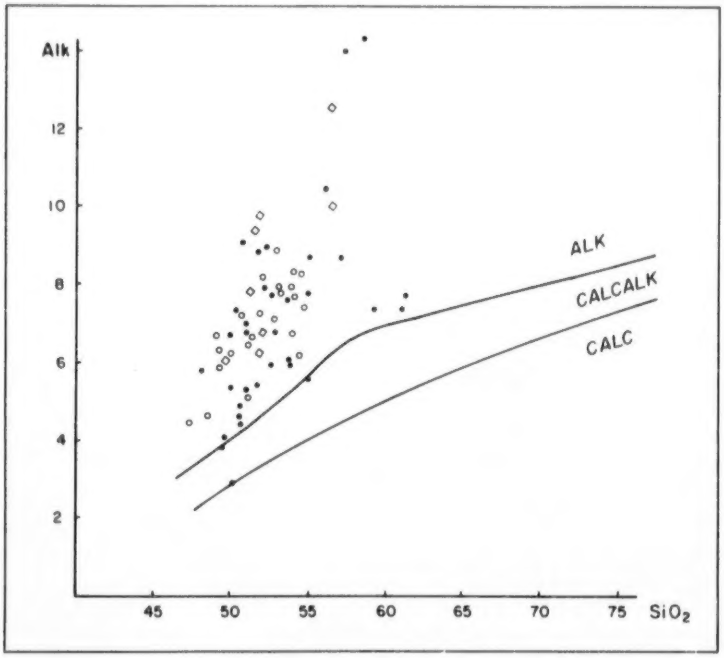


Figure 140. Upper Triassic shoshonites. Alk:SiO_2 plot illustrates the alkaline nature of the shoshonites. The extremely alkaline samples are leucite phonolites. Boundaries from Kuno (1966), high-Al domain relabelled 'calc-alkaline' and thoelitic domain 'calcic'.

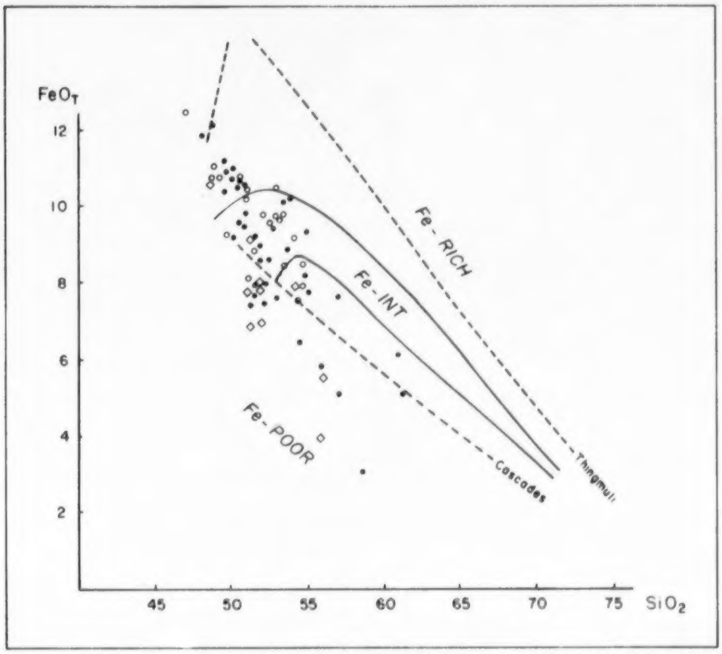


Figure 141. Upper Triassic shoshonites. FeO$_T$:SiO$_2$ plot. 'Fe-rich' (tholeiitic) and 'Fe-poor' (calc-alkaline) domains defined from plot of pigeonitic and hypersthenic suites of Japan. 'Fe-intermediate' domain is a zone of overlap (de Rosen-Spence, 1976).

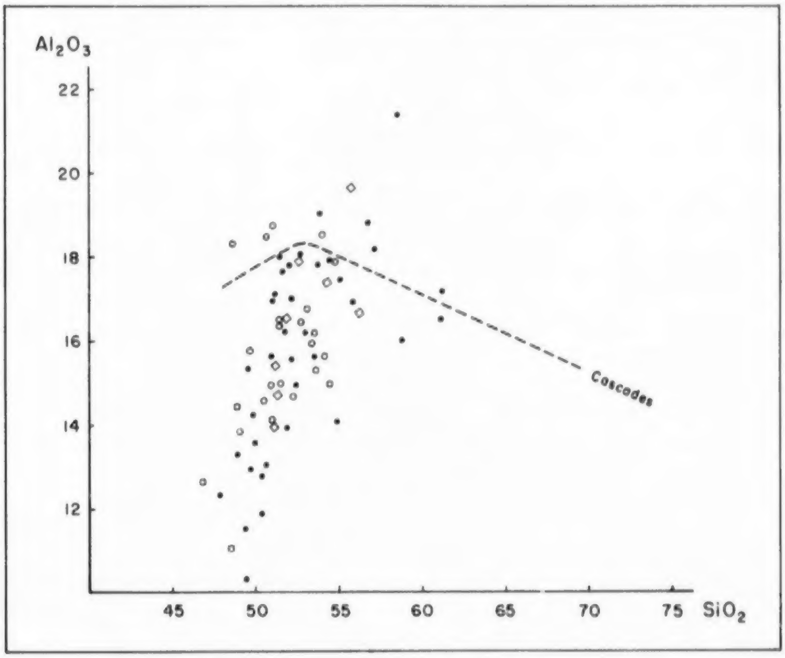


Figure 142. Upper Triassic shoshonites. Al$_2$O$_3$:SiO$_2$ plot shows the increase in Al$_2$O$_3$ with differentiation.

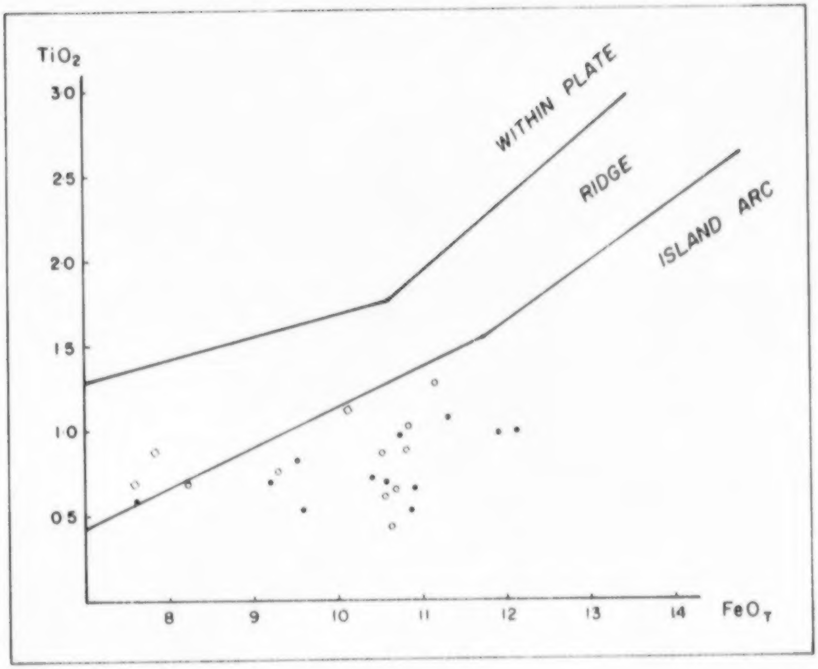


Figure 143. Upper Triassic shoshonites. TiO_2:FeO_T designed initially for subalkaline basalts with 48 per cent ≤ SiO_2 ≤ 50.5 per cent (de Rosen-Spence, 1976).

THE MAC PORPHYRY MOLYBDENITE PROPERTY, CENTRAL BRITISH COLUMBIA
(93K/13E)

By C. I. Godwin
Department of Geological Sciences, University of British Columbia
and
R. Cann
Rio Algom Exploration Inc.

INTRODUCTION

The Mac porphyry molybdenum property in the Intermontane Belt, 100 kilometres east of Smithers and 47 kilometres north-northwest of the south tip of Babine Lake, was discovered in 1982 by follow-up prospecting based on lake-sediment geochemical anomalies. There is about 2 per cent outcrop in the heavily timbered and covered area of the showings.

GEOLOGY

Regionally the Mac deposit is within a north-northwest-trending belt of Carboniferous or Permian greenstone, argillite, and chert (Armstrong, 1949). Near the property, these rocks are intruded by elongate, narrow bodies of peridotite and gabbro that are assigned to the Mesozoic Trembleur intrusions, and by granitic bodies assigned to the Upper Jurassic or Lower Cretaceous Omineca intrusions. These intrusions, dated as Lower Cretaceous (Table 1), are similar to the Topley intrusions (White, *et al.*, 1970) in age, molybdenum association, and initial strontium isotope ratios (Table 2).

Major units near the Mac property are shown on Figure 144. Schistose, actinolitic, chloritic basic metavolcanic rocks (Fig. 144, unit 1), and metaserpentinite bodies (unit 2) have been intruded by Lower Cretaceous (Table 1) granitic stocks consisting of medium-grained, biotite granodiorite (unit 3), and medium-grained, leucocratic quartz monzonite (unit 4). The granodiorite apparently generated a hornfelsic aureole up to 1 000 metres wide in the intruded units (Fig. 144). The hornfels is characterized by lack of schistosity, 2 per cent disseminated pyrite with lesser pyrrhotite, and local, weak biotitization. Quartz monzonite apparently intrudes the hornfels; therefore the quartz monzonite is at least somewhat younger than the granodiorite.

MINERALIZATION

Most of the molybdenite occurs in microveins and in quartz veins. These form stockwork and sheeted zones in the medium-grained leucocratic quartz monzonite host rock (Fig. 144). Only traces of molybdenite are found in

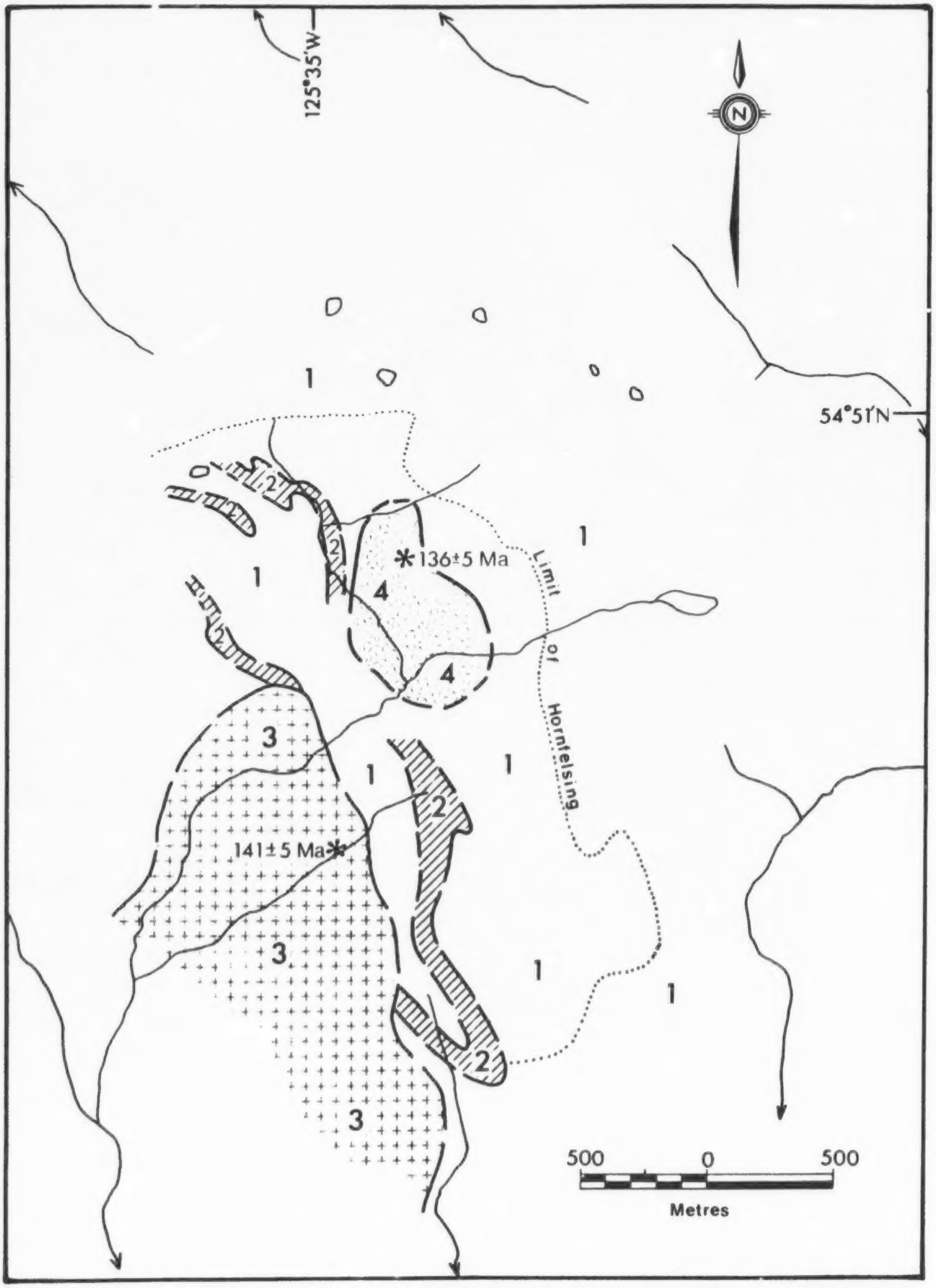

125°35'W
54°51'N
N
1
2
3
4
136±5 Ma
141±5 Ma
Limit of Hornfelsing
500
0
500
Metres

Figure 144. Generalized geology of the Mac porphyry molybdenum prospect. Units shown are: 1 — schistose, basic metavolcanic rocks; 2 -- metaserpentinite; 3 — biotite hornblende granodiorite; 4 -- leucocratic quartz monzonite. K/Ar date of 141±5 Ma is from sample G84MAC1 (Tables 1 and 2); date of 136±5 Ma is from G84MAC4 (Table 1).

microveins and quartz veins in the hornfels near the contact with the stock. Surface outcrops of the quartz monzonite commonly show no molybdenite and only traces of ferrimolybdite, but about 20 trenches and pits reveal molybdenite in freshly broken rock that is more than 1 centimetre in depth. Grades obtained in many of the areas sampled are between 0.018 and 0.166 per cent molybdenum. Limits of the mineralization have not been defined, however, trenching and pitting have exposed mineralization over a rectangular area which is about 500 metres long (northwest-southeast) and 200 metres wide.

Quartz-molybdenite veins contain less than 1 per cent pyrite and minor amounts of chalcopyrite. Alteration, which is generally weak, is most intense within a few centimetres of the veins. Envelopes of sericitic alteration are characteristic, but rare envelopes contain secondary biotite.

K-AR AND RB-SR ISOTOPE DATA

Potassium-argon dates on biotite from a regionally extensive granodiorite, and from altered leucocratic quartz monzonite associated with molybdenite mineralization, yielded Lower Cretaceous ages of 141±5 and 136±5 Ma respectively (Table 1). These dates are close to the Jurassic-Cretaceous boundary at 143 Ma (Armstrong, 1978) or 144 Ma (Harland, *et al.*, 1982). These ages are indistinguishable from those from the Topley intrusions (White, *et al.*, 1968; White, *et al.*, 1970) which contain the major Endako molybdenite porphyry mine, 95 kilometres south-southeast of the Mac property.

The initial ^{87}Sr to ^{86}Sr ratio of 0.7035 for the granodiorite (Table 2) is typical for most of plutonic rocks in this part of the Intermontane Belt of the Canadian Cordillera (R. L. Armstrong, personal communication, 1984). This ratio is slightly lower than those for the Topley intrusions in the Endako area, which are 0.7040 (R. L. Armstrong, unpublished data), for values from the Intermontane Belt near Whitehorse, Yukon Territory, which are 0.704 to 0.705 (Morrison, *et al.*, 1979), and for intrusions at Quartz Hill, Alaska, which are 0.705 (Karimpour and Bowes, 1983). Initial ratios from intrusives associated with molybdenum, tungsten, and tin deposits, which are emplaced in thick sequences of crustal rocks, tend to be markedly higher. Examples of this include 0.706 to 0.713 for the 'eastern suite' described in the northern and eastern part of the Canadian Cordillera (Sinclair, in press), and 0.706 to 0.710 for the Henderson type of molybdenum deposit in Colorado (Karimpour and Bowes, 1983).

CONCLUSIONS

The Mac property represents a new, significant molybdenum porphyry prospect. The geological setting, age, and initial strontium isotope ratios are very similar to those of the Topley intrusions, which host the

TABLE 1. Potasium-argon data from biotite for granitic rocks near the Mac property, central British Columbia.

Sample number	Location lat(^{o}N)	 long(^{o}W)	Rock unit and rock name	%K (±)	$\frac{^{40}Ar^*}{^{40}Ar_{total}}$ ^{2}	$\frac{^{40}Ar^*}{10^{-5}\ cm^3\ STP/g}$ ^{2}	Apparent age (Ma)^3	Time^4
G84MAC1BI	54.85	125.58	Medium grained biotite granodiorite	6.34 0.03	0.970	3.6220	141 ± 5	Lower Cretaceous
G84MAC4BI	54.86	125.58	Medium grained leucocratic quartz monzonite	6.82 0.13	0.961	3.7439	136 ± 5	Lower Cretaceous

1. Argon analyses are by J. Harakal and potassium analyses are by K. Scott; all analyses were done at the Geochronology Laboratory, The University of British Columbia
2. Ar^* indicates radiogenic argon
3. Constants used are from Steiger and Jager (1977): $\lambda_e = 0.581 \times 10^{-10}\ yr^{-1}$; $\lambda_\beta = 4.962 \times 10^{-10} yr^{-1}$; $^{40}K/K = 1.167 \times 10^{-4}$
4. Time designation is from Armstrong (1978) and Harland et al. (1982).

TABLE 2. Rb-Sr analyses of granitic rock from near the Mac property, central British Columbia.

Number[1]	Sample description[1]	Latitude degrees N	Longitude degrees W	Sr ppm	Rb ppm	Rb/Sr	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$	Initial ratio[3]
G84MAC1WR	Medium grained biotite granodiorite	54.85	125.58	334.8	72.96	0.218	0.6306	0.7047 ± 2	0.7035

1. Sample location is plotted on Figure 1. Analysis was on a whole rock sample.
2. Aralyses were done in the Geochronology Laboratory by K. Scott under the direction of R.L. Armstrong at The University of British Coulumbia.
3. K-Ar date (141 Ma) for biotite from the same sample was used in the calculation of the initial ratio.

Endako molybdenum porphyry deposits. The lower initial strontium ratio from a pluton related to the Mac deposit, compared to those plutons associated with the 'eastern suite' of Sinclair (in press), implies that the former had an ultimate source that involved a lesser volume of old, sialic crustal rock (*see* Godwin, *et al.*, 1980).

ACKNOWLEDGMENTS

The writers thank Rio Algom Exploration Inc. for permission to publish and for financial support. Lisa Holmgren and Colin Spence of Rio Algom Exploration Inc., respectively, assisted in the sampling and review of the manuscript.

REFERENCES

Armstrong, J. E. (1949): Fort St. James Map Area, Cassiar and Coast Districts, British Columbia, *Geol. Surv., Canada,* Mem. 252, 120 pp.

Armstrong, R. L. (1978): Pre-Cenozoic Phanerozoic Time Scale - Computer File of Critical Dates and Consequences of New and In-progress Decay-constant Revisions, *in* Contributions to the Geologic Time Scale, G. V. Cohee, M. F. Glaessner, and H. D. Hedberg, editors, *Am. Assoc. Petrol. Geol.,* Studies in Geology No. 6, 388 pp.

Godwin, C. I., Armstrong, R. L., and Thompson, K. M. (1980): K-Ar and Rb-Sr Dating and the Genesis of Tungsten at the Clea Tungsten Property, Selwyn Mountains, Yukon Territory, *C.I.M.,* Bull., Vol. 73, No. 821, pp. 90-93.

Harland, W. B., Cox, A. V., Llewellyn, P. G., Pickton, C.A.G., Smith, A. G., and Walters, R. (1982): A Geologic Time Scale, *Cambridge Univ. Press,* 131 pp.

Karimpour, M. H. and Bowes, W. A. (1983): Application of Trace Elements and Isotopes for Discriminating between Porphyry Molybdenum, Copper and Tin Systems and the Implications for Predicting the Grade, *Global Tect. Metal.,* Vol. 2, pp. 145-150.

Morrison, G. W., Godwin, C. I., and Armstrong, R. L. (1979): Interpretation of Isotopic Ages and Sr/ Sr Initial Ratios for Plutonic Rock in the Whitehorse Map Area, Yukon, *Cdn. Jour. Earth Sci.,* Vol. 16, No. 10, pp. 1988-1997.

Sinclair, W. D. (in press): Molybdenum, Tungsten and Tin Deposits and Associated Granitoid Intrusions in the Northern Canadian Cordillera and Adjacent Parts of Alaska, *in* Northern Canadian Cordillera, *C.I.M.,* Special Vol.

Steiger, R. H. and Jager, E. (1977): Subcommission on Geochronology: Convention on the Use of Decay Constants in Geo- and Cosmochronology, *Earth Planet. Sci. Lett.,* Vol. 36, pp. 359-362.

White, W. H., Harakal, J. E., and Carter, N. C. (1968): Potassium Argon Ages of Some Ore Deposits in British Columbia, *C.I.M.*, Bull., Vol. 61, pp. 1326-1334.

White, W. H., Sinclair, A. J., Harakal, J. E., and Dawson, K. M. (1970): Potassium Argon Ages of Topley Intrusions near Endako, British Columbia, *Cdn. Jour. Earth Sci.*, Vol. 7, No. 4, pp. 1172-1178.